Robert Gerwin

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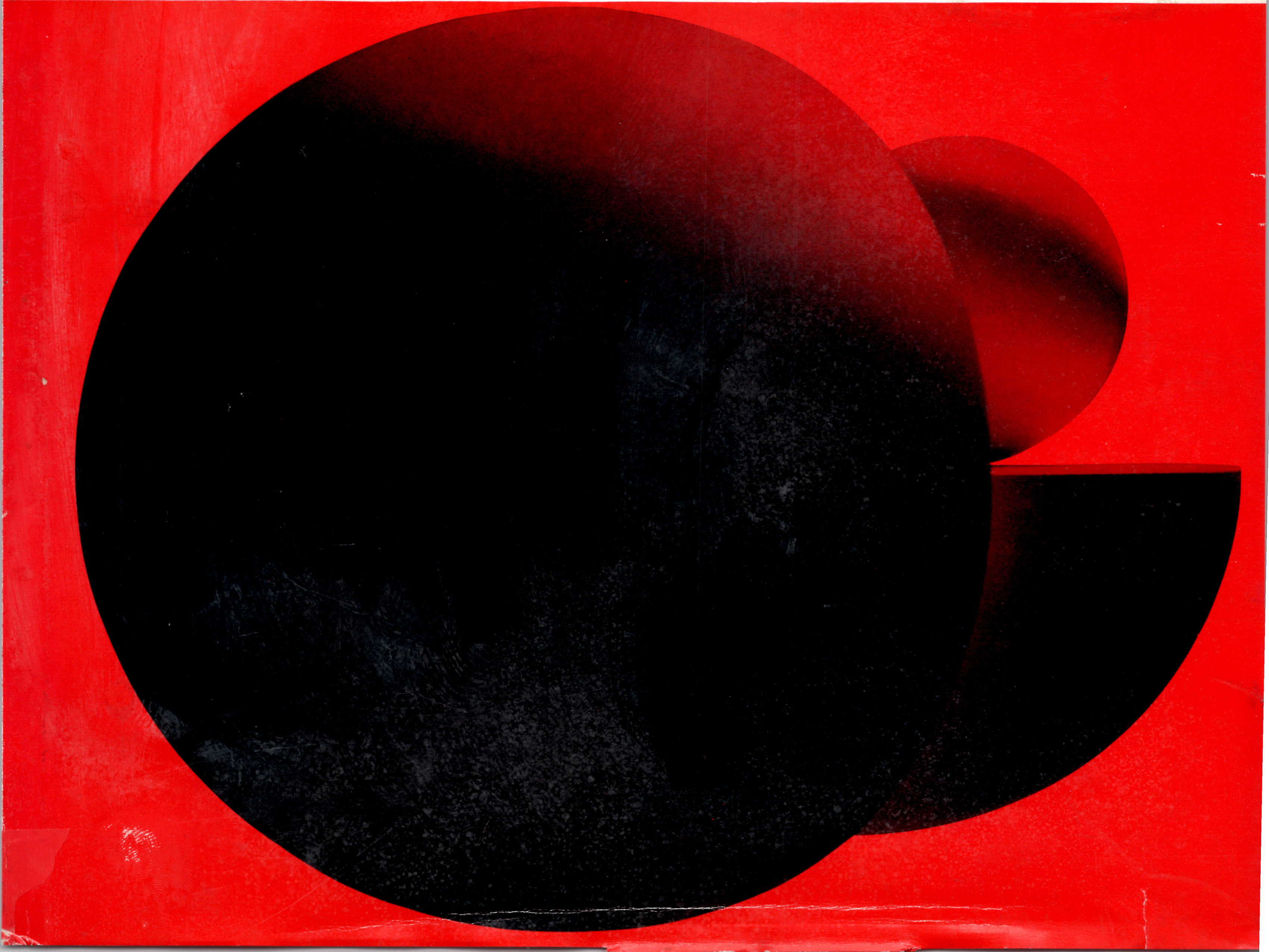
Atoms in Germany

A report on the state and development of nuclear research and nuclear technology in the Federal Republic of Germany



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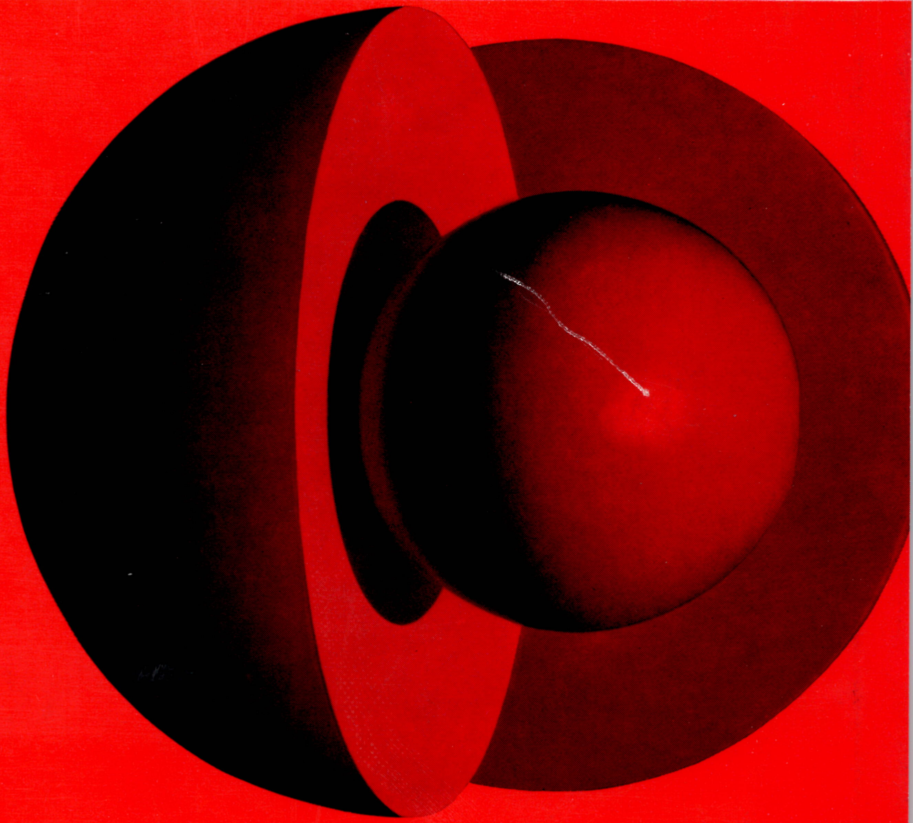

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Considering the development of nuclear research and technology in the world one will get the impression that this development is characterized by sometimes rather individual features.
This certainly applies in particular to the Federal Republic of Germany which—except for the first beginnings of a nuclear reactor development during the war—was debarred from tackling problems of the peaceful utilization of nuclear energy until 1955 and which could not go back on a military nuclear development. In the present report the effort has been made to depict, in a summarizing form, the developmental phase as well as the present state of nuclear research and technology in the Federal Republic of Germany. In particular, the author endeavoured to hammer out the historical background and some developmental coherences so that the interested layman as well as the overspecialized expert might get a good idea of what has far been done in the Federal Republic. Special mention has been made of the German Atomic Energy Programme and it has been tried to describe the activities of research centres and industrial development groups. A number of leading personalities of German nuclear research, nuclear industry and nuclear administration have, it is true, contributed to this report, but even though it is the work of an independent scientific author.

It was written for the third International Conference on the Peaceful Uses of Atomic Energy but beyond this specific purpose it might also be considered a general document covering the first decade of nuclear development in Germany.

Design of cover and jacket: Rolf Lederbogen

ROBERT GERWIN ATOMS IN GERMANY

Robert Gerwin

Issued in cooperation with
the Bundesminister für wissenschaftliche Forschung · August 1964 · Econ-Verlag

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PREFACE

The Third International Conference on the Peaceful Uses of Atomic Energy, and in particular the governmental scientific exhibition organized under its auspices are of special importance for the Federal Republic of Germany. It is the first conference of its kind where the German participants are not only the ones to receive but also the ones who can give. For the first time the Federal Republic of Germany comes to the international partly with its own accomplishments in the fields of nuclear technology and research and for the first time the German contribution to the exhibition is more or less comparable to that of the "classical" European nuclear countries such as Great Britain and France.

Thus the idea suggested itself to submit a report on the present state and the previous and future development of nuclear research and nuclear technology in the Federal Republic of Germany in addition to presenting papers at the conference and organizing the so-called governmental scientific exhibition. This report is published for members of foreign delegations and conference participants who are not too familiar with the development of nuclear energy in Germany but who would like to get a general idea of it. However, this report is also addressed to the experts and interested quarters in the Federal Republic and due to its summarized form, it should cause them to look back and to ponder about the future. Being a survey only this report cannot be a true and complete image of the activities of every research group, institute, and developmental department in Germany. In particular it cannot possibly state the names of all the personalities concerned. Instead it tries–not without some self-criticism–to point out common tendencies of development and coherences, which are not always obvious.

A number of leading personalities of the German Atomic Energy Advisory Committee, competent officials from the Federal Ministry for Scientific Research and scientists and engineers from all major research and development centres in the Federal Republic are closely connected with this report which, however, does not constitute an official document. It is the work of an independent scientific author seen from his point of view.

The author is greatly indebted to many individuals in the nuclear industry and nuclear research in Germany for the valuable suggestions and information which they have given him over the years or with a view to this special occasion. It is impossible for me to thank all of them individually. It was above all Dr. Hans Sauer who helped me with his expert knowledge and in many an organizational aspect so that I would like to thank him in particular. I am also indebted to Professors Heinz Maier-Leibnitz and Karl Wirtz for their thorough perusal of the initial manuscript.

I. GERMANY'S PARTICULAR SITUATION

The following event occurred during the first Geneva Conference on the Peaceful Uses of Atomic Energy in 1955. At that time the undisputed focus of the governmental scientific exhibition was no doubt the swimming-pool reactor which the American delegation had brought along. It was not only the first reactor of its kind in Europe but the first reactor at all to which a larger number of interested visitors and experts had ready access without any formalities. One day an elderly gentleman with shaggy eyebrows, a cigar in his hand, appeared in the reactor control-room which was shielded by a special wall of glass. He asked the operator on duty in fluent English but with an unmistakable German accent:

"May I, too, try and set your fine reactor going?"

The operator submitted to the joke and asked back: "Okay, old guy, do you know anything about atoms?"

"Well, I think so," answered the gentleman with the cigar, "because I discovered the splitting of the atomic nucleus. My name is Otto Hahn."

This answer made the operator laugh even more. Not even the embarrassing silence around him put him out. When finally one of the gentlemen accompanying Professor Hahn confirmed the latter's identity, the American rose in defence declaring: "You cannot possibly know all the people that are in the atomic business."

Later on when Otto Hahn visited the other booths of the scientific exhibition, including the impressive American pavilion, he made the same experience. Neither did people recognize him, nor did his name leave any impression on them. One was almost tempted to quote from the Bible: "He came unto His own, and His own received Him not."

At that time this episode was not only reported by some American papers as a curiosity among the important events of this great conference, but it was also to be found in the German press, where it was not so much depicted as a funny thing but rather as the obvious sign that we, in Germany, had considerably fallen behind in nuclear research and technology with regard to the general level of development.

Meanwhile, 9 years have elapsed and much has been done in Germany to remedy the 1955 situation effectively. And yet, if Otto Hahn were to visit the Third United Nations Conference on the Peaceful Uses of Atomic Energy and were to stroll through the so-called governmental scientific exhibition he would probably make the same experience. The reason for this would not be the frequently quoted lack of respect of the young generation towards the old one but the fact that nuclear research and nuclear technology in the world have led up to something fundamentally new which has less in common with conventional science than is generally perceived–at least in the Federal Republic of Germany. Otto Hahn belongs to the circle of legendary scientific personalities–in the eyes of the young generation–who were able to make fundamental discoveries more or less on their own and with comparatively moderate technical means. Meanwhile–and this is particularly true of the nuclear energy field under consideration–another style of work has developed and there are only a few links to that in which scientific research was conducted in the past decades. That is why to a certain extent Otto Hahn was almost a stranger in his own house in 1955 and is even more so in 1964.

What connection is there between these considerations and a report describing the state and development of nuclear research and technology in Germany? Well, those who have a closer look at this state of development will automatically draw parallels to the developments in other countries and in doing so they will come across considerable differences. We need not go into the questions as to whether such a comparison works out favourably or unfavorably for the Federal Republic–the final judgement, of course, can only be given after many years have elapsed–but it is interesting to know the reasons why development has taken such different courses. Trying to find a common denominator for these reasons, one is inclined to think that they are the consequences of certain ideal concepts of the nature of science which are no longer up to date.

Every European visitor to scientific institutions in the United States is enthusiastic about the whole-heartedness with which Americans tackle huge research and development projects. In the Federal Republic, too, one came to realize quite some time ago that the promotion of science is one of the vital tasks of our time, yet it is not clearly recognized everywhere that the essence of these vital scientific activities has for good reasons deviated–and in some parts rather considerably–from the ideals of Alexander von Humboldt. Up to the nineteen–thirties, Germany had been a country with a high scientific level and a long-established scientific tradition. We, in this country, now find it difficult to adapt ourselves to the new style, including the fact that scientific achievements require expensive equipment which does not only cost a considerable amount but which also makes "pure" science become directly dependent upon technology. Whereas 25 years ago a bench with a few measuring instruments, which to us nowadays appears downright primitive, sufficed to enable such a fundamental discovery as that of nuclear fission, one is prepared to accept–not without some hesitation–that scientific achievements are unthinkable without technological peak performances. In a country which is much less burdened by tradition, such as the United States, where, in addition, one is used to a much more pragmatic way of thinking, such an adaptation takes place much more smoothly.

In addition to these more-or-less emotional reasons accounting for the originality of nuclear energy development in the Federal Republic of Germany, there are others which are material and conspicuous. Nuclear development in Germany cannot rely upon the development of nuclear weapons or any other kind of military utilization of nuclear energy. There was, therefore, no possibility to transfer certain research and development costs to military projects or to take over certain pilot plants and production facilities which had become superfluous for weapons development. Nor has Germany ever had a development of water reactors for submarines. On the other hand the German engineers and scientists who engaged in nuclear research and technology were not faced with many heavy scruples or restrictions of their activities due to military secrecy instructions. The overwhelming majority of them are content with this development and readily put up with the less favourable starting conditions they found in Germany.

Thus, however, the civil nuclear energy development is faced with the thankless task to make the general public in Germany aquainted with what is termed "big science" and, of course, what it means to engage in big science. In the United States, in the Soviet Union, and finally in Great Britain and France the big national research centres were at first established exclusively–or at least primarily–with a view to the military applications of nuclear energy. The same analoguously applies to the development of a nuclear industry.

When in 1953 President Eisenhower proposed his famous Atoms-for-Peace Programme to the United Nations the first steps were made on the way towards peaceful utilization of nuclear energy in the U.S.A. and the other nuclear powers. The existing national laboratories almost demanded a new great challenge. In the Federal Republic of Germany, however, every kind of nuclear activity (even that for peaceful purposes) had been expressly banned by the Allied Forces up to 1955. Thereupon research centres had to be established along the lines of the national laboratories and this for the only purpose of the peaceful utilisation of nuclear energy. From the very outset the development of nuclear research and nuclear technology was, as far as it aims at an industrial utilization, burdened by the problem of commercial efficiency. Thus it may be said that in Germany the atom has to sell itself by the mere promises it held as a research project, as a new source of energy, and as a pacemaker for new technologies. Up to now the situation has, in principle, remained unchanged.

This "market situation" is particularly aggravated by the fact that, owing to the federal structure of the Federal Republic of Germany and to the express private-enterprise concept of its economy, the promotion of specific projects of nuclear research and technology will encounter considerable difficulties even if it were only for formal reasons. As opposed to Great Britain, France and Italy electricity supply in the Federal Republic of Germany is not in hand of the Government or Government-owned companies but of private enterprises and communities. The German Laender, it is true, and the Bund itself have an important share in the private electricity supply companies which, however, are operated on a private-enterprise basis thus keeping in line with the principles of a free-market economy. In other words–or to put it somewhat simpler–the Federal

Government cannot force an electricity supply company to build a nuclear power station if this company has not itself arrived at the conclusion that such a project would be reasonable from an economic point of view Accordingly the Government's possibilities to financially promote the construction of nuclear installations of private electricity supply companies are to some extent limited. It has to confine itself more-or-less to give letters of indemnity and to provide coverage for guarantees so that it cannot be blamed for giving only partial support to one source of primary energy. It goes, without saying, therefore, that the Government would not build its own nuclear power stations out of public funds. When an experimental nuclear power station was to be set up in Germany on the basis of the pressure vessel reactor design with heavy water as a moderator, this power reactor had to be equipped with several beam holes so that it could be entered as a multi-purpose research reactor and set up with Federal funds.

When pursuing a declared research project, the Bund, on the other hand, will easily run into competing problems with the German Laender which according to the Basic Law are autonomous so far as their cultural policy is concerned. And it is a long-established tradition that in German language usage science comes under the heading "Kultur", a term by the way which in this meaning has hardly an equivalent in any other language. Today we cannot blame the fathers of the Basic Law that they did not forsee the development of big science in 1949 when the country was devastated and ruined. At that time they were under the impression of the losses which natonal socialism had inflicted upon the scientific life of our country during the thirties and fourties, and that is why they thought they should protect the development of science in Germany against too strong central governmental agencies. The consequence has been that, in spite of the Federal Act on the Peaceful Uses of Atomic Energy and the existence of a Federal Ministry for Scientific Research, a certain rivalry has developed between the Bund and the Laender in promoting and controlling the development of nuclear research and technology.

This rivalry has not always proved to be a disadvantage. Thus, for instance, the Land Northrhine-Westphalia set up the large nuclear research establishment at Jülich almost exclusively from its own means, and has thus gone far beyond its liabilities to contribute to nuclear research, if such a liability even exists. In many cases it is easier for the Laender to promote specific development projects than it is for the Bund to do so given its tight budgetary situation. On the other hand, since the Bund has to take into account the touchiness of the Laender with regard to their cultural sovereignity it is frequently forced to go to lengthy negotiations. Furthermore, research and development projects may easily become a tool of political forces, such as in disputes on fiscal policy arising between the Bund and the Laender.

Such political threat also arises because the central organ responsible for nuclear research and technology in the Federal Republic is not an independent authority but one which is fitted into the traditional administrative pattern of the executive, i. e., a Ministry of the classical concept with a budget running for one year only and headed by a Minister exposed to political constellations. In the United States, in Great Britain, and in France, however, independent and accordingly flexible new-type organizations were set up for the central handling of big science. In this connection we need only think of the Atomic Energy Commission (AEC), the National Aeronautics and Space Administration (NASA), the Atomic Energy Authority (AEA), the Commissariat à l'Energie Atomique (CEA), and the Centre National d'Etudes Spatiales (CNES). The constitutional distribution of competensiveness between the Bund and the Laender being what it is, such well-proven organizations cannot easily be copied by Germany.

However, it will not be possible for us to stop looking for new form of organization even if it were only for the legal status of bodies sponsoring big scientific and technical projects, as in the case of the construction and operation of the "national laboratories", such as the Karlsruhe nuclear research centre and the Institute of Plasmaphysics at Garching near Munich. For the time being these large centres have been given the form of private companies with limited liability (GmbH). Unlike other alternatives such as private foundations, registered societies, or federal institutions the GmbH is above all characterized by a great flexibility and the possibility of pursuing a personnel and management policy along industrial lines. On the other hand, it is true, such a company cannot possibly discharge functions of the government which is necessary above all in the nuclear energy field. It cannot readily represent the Federal Republic at international conference and it cannot be responsible to Parliament for the proper spending of funds. In addition there is an inflexibility as far as staff policy is concerned. In many cases it would be a good idea and would be in the interests of both parties concerned as well as to the benefit of representation at international meetings if scientists and administrators of the Ministry and of research centres could be exchanged. Yet such an exchange will hardly be possible as long as the time which a ministerial officer spends in the service of a GmbH is not officially credited. These problems seem to be of minor importance and yet they are decisive factors for shaping the development of nuclear research and technology in Germany. Some 350 years ago the great astronomer Johannes Kepler wrote: "I consider the ways by which people come to know the universe almost as admirable as the nature of things themselves." It may seem a little trivial to put a science such as astronomy on a level with the development of nuclear technology and research. Nevertheless it can perhaps be said of this development, too, that it is not so much the result of research and activities which are impressive but the way in which human society faces up to it. The way chosen by Germany is certainly only one out of a great many. Presumably it is not even one of the most efficient nor one of the most spectacular ways. Still it may be a little better than it often appears to us, those immediately concerned. At least it is unique and has no equivalent in other comparable countries. It is the way of a country hard hit by the aftermath of the war and a little handicapped by a traditional way of thinking; a country, where some of the old ingenuity and genius is still alive that once enabled her to hold a leading position among the major countries of science of the world, even in the nuclear energy field.

II. 25 YEARS OF NUCLEAR FISSION IN GERMANY

Historical Survey

18 When all efforts to liberate the energy of the atom were still in the very beginning, there was indeed a short period of time when Germany was a little ahead of America und all other working groups in the world. That was more-or-less at the turn of the year 1941/42. However, this German lead was not at all as spectacular as was believed in the U.S.A. at that time–and it did not aim at the construction of an atomic bomb but merely the development of a so-called “chain reaction unit". Today we would call this unit a nuclear reactor, or, to be more correct, a subcritical assembly.

Karl Friedrich von Weizsäcker stated some years ago that “it was somewhat dramatizing things to say that we had intentionally avoided or prevented production of the bomb, since we knew at that time that we were not able to do so. We decided to attempt building a reactor. However, we did not endeavour to produce a bomb."

1. GERMAN ACTIVITIES DURING THE WAR

The historic discovery of nuclear fission by Otto Hahn and his co-worker Fritz Straßmann in December 1938 has so often been described–by Otto Hahn also–that we need not repeat it here. Seen from the nuclear physics aspect it was the work of an outsider. Otto Hahn has protested time and again whenever he was classified a physicist and not a chemist, and, in the light of the then prevailing way of thinking and approach, perhaps only a chemist was able to arrive at the decisive conclusion that the presumed transuranic elements which were produced by bombarding uranium nuclei with neutrons, actually were uranium fission products. These phenomena were not only studied by Otto Hahn but also by Fermi in Rome and Irène Curie in Paris. In the first note which Hahn published in the periodical "Die Naturwissenschaften" of December 22, 1938, we find the characteristic restriction: "As chemists we ought to say that these new bodies are barium and not radium. As 'nuclear chemists' we cannot yet jump to this conclusion, which is contradictory to all our previous experience in nuclear physics." When questioned about this cautious remark, Hahn later declared: "Our hesitation was not due to any doubt in our results but to our respect of physics which made us, the chemists, overcautious. We were too much bound by the rule of physics that there cannot be what must not be."

Furthermore, we know how a direct note to Hahn's former collaborator, Lise Meitner, and her nephew O. R. Frisch led to the discussion about the physical possibility of a nuclear fission chain reaction, a discussion which was rapidly taken up in the U.S.A., France, and England. In March and April 1939 respectively, Halban, Joliot and Kowarsky gave the well-known information that a chain reaction to produce nuclear energy should, in principle, be possible. These publications caused the Hamburg professor Paul Harteck to write to the then Reichskriegsministerium (Ministry of War) pointing out that, due to the discovery of Hahn it had now, in principle, become possible to produce a new type of powerful explosives. According to a statement of the then competent official in the Heereswaffenamt (Army Ordinance Department), Kurt Diebner, this letter, dated April 24, 1939, made Germany take an official interest in the release of nuclear energy. However, things proceeded still very slowly, mainly because nuclear physics was not very much favoured officially at that time.

An article by S. Flügge, one of Otto Hahn's assistants, which was published in "Naturwissenschaften" in June 1939, attracted considerable attention not only in Germany but also in other countries; its title "Kann der

Energieinhalt der Atomkerne technisch nutzbar gemacht werden?" (Is it possible to exploit the energy contained in atomic nuclei for technical purposes?) seemed sensational at that time. Flügge's answer to the question he had raised was: "Our present knowledge is such that we may well think of building an uranium machine." Flügge also developed something like a theory for the production of nuclear energy and gave hints as to how one should proceed in practice.

At that time, Szilard and Wigner in the U.S.A. visited Albert Einstein in order to co-opt him for an official American activity in this field. On August 2, 1939, Albert Einstein wrote his famous letter to President Roosevelt. The latter thereupon convened the Advisory Committee for uranium matters.

On September 26, 1939, the first official discussion took place in Germany at which competent nuclear physicists were asked whether or not they thought it reasonable for Heereswaffenamt to assume responsibility for initiating a major programme of nuclear energy production. If so, a working programme had already been prepared for discussion and decision. Of course, only the construction of a reactor–a uranium machine as it was then called–was at stake. First of all, proof had to be rendered that a nuclear fission chain reaction could be realized.

Indeed, the nuclear physicists gave their consent and at this first meeting the fundamental proposal was accepted that the uranium had to be separated in space from the moderator, and that it was necessary to look for heavy water. It was agreed to intensify the measurement of the cross-section of uranium and other constructional and moderating materials concerned, and to invite to the next meeting theorists like Werner Heisenberg and isotope separation experts like Klaus Clusius. This second meeting took place at the beginning of October 1939, and later that very month Heisenberg already submitted a much advanced theory of energy production by fissioning the uranium nucleus, a theory which was to become of fundamental importance for all further studies of the so-called "Uranverein"–the team of scientists working in Germany towards producing nuclear energy.

The first meeting of the uranium committee convened by Roosevelt took place on October 21, 1939, but on this occasion the problem was only discussed generally, and it was merely proposed to procure 4 t. of graphite and 50 t. of uranium oxide.

In Germany experimental investigations on certain layer arrangements were taken up some time in May, 1940. At first a relatively small amount of 185 kg. of uranium oxide and 15 t. carbon dioxide snow as a moderator were used. Later, the carbon dioxide was replaced by paraffin and in 1941 uranium oxide was replaced by powdered uranium metal. Heavy water, too, had at least to some extent become available since the autumn of 1941. Experiments were under way in Hamburg, Berlin, Heidelberg, and Leipzig. It was especially Leipzig which became the centre of main effort under Heisenberg.

In the U.S.A. the uranium committee was made a sub-organization of the Research Committee for National Defense only in June 1940. It awarded its first research contract on November 1, 1940. Up to November 1941, 16 research projects were approved for which a total of $ 300,000 were raised. Quite similar to the work performed in Germany arrangements of uranium and moderating substances were tested at Columbia University under the direction of Fermi from July to December 1941, the only difference being that in the U.S.A. graphite was chosen instead of paraffin and heavy water. According to Diebner and others it was primarly due to the good results of the Leipzig experiments that work in Germany was somewhat in advance of the American activities headed by Fermi and his group in the late autumn of 1941.

At the turn of the year 1941/42 two fundamental decisions were taken in Germany as well as in the U.S.A. with regard to organization. On December 16, 1941, a discussion was held in the research division of Heereswaffenamt with all the leading personalities of the German Uranverein; the question was raised in due form whether, with regard to the raw material scarcity caused by the war, it would be acting irresponsibly to invest further into this project. It was the very moment when, for the first time, in Russia, the German Wehrmacht had to retreat from the outskirts of Moscow. Thus the general instruction was issued to promote only such development projects which promised success within a reasonable period of time. The official decision was again put off until submission of a survey. From 26 to 28 February a meeting was held at the Kaiser-Wilhelm-Institut for physics in Berlin where all working groups taking part in the development of the uranium machine presented their results. It became quite obvious that it would be possible to build a nuclear reactor, however, no-one in the Uranverein could promise definitely that such a unit would be available for military application within 9 month. Thus the uranium project was taken from the Heereswaffenamt and placed under the control of the Reichsforschungsrat (Reich Research Council). It was to be carried on merely as a proper research project, but the costs were to remain in the same order of magnitude. Such a decision was deemed reasonable by most members of the Uranverein after they had recognized that it was possible to develop an atomic bomb only on the basis of isotope separation or on the basis of the production of the element 98. The technical effort necessary could no longer be made by the Deutsche Reich at that time; it was thought in Germany that such effort would have to be so enormous that even the U.S.A. could not possibly afford it.

In the U.S.A., however, a meeting of the supreme planning group of the Research Committee for National Defence took place, in which the Minister of War participated and at which it was decided "to press as much as possible for the finding of the physical basis as well as for the furtherance of the technical plans, in particular the erection of experimental plants". Research activities were largely regrouped and the whole organizational set-up was strengthened and expanded. Results soon became evident. On December 2, 1942, Fermi was able to take into operation his first chain reaction unit with a power of half a watt in Chicago; this was the first zero-power assembly in the history of nuclear technology.

This success was denied Germany up to May, 1945, i. e., the end of the war. After the Kaiser-Wilhelm-Institut for physics had moved from Berlin to Hechingen what is now Baden-Württemberg and after concentrating all supplies and all manpower Karl Wirtz and a number of his co-workers endeavoured for the last time to get a uranium machine operating in a vault at Haigerloch in the winter of 1944/45. There were altogether 1.5 t. of uranium and about 2 t. of heavy water available. They were accomodated in a cylindrical vessel of 2.1 m. height and of 2.1 m. diameter surrounded by a graphite shell which served as a neutron reflector. However, it became evident that the amount of fuel and moderator inserted was not sufficient to achieve a critical assembly. With this geometry an additional 50% would have been needed. Perhaps the experiment could have been successful if the form of the reactor vessel had been a sphere and not a cylinder. But who does bother about that today? At the same time numerous plutonium reactors were already operating in the U.S.A. with an output of some thousand megawatts.

Otto Hahn did not participate in any of these activities. Up to the end of the war he had discovered about a hundred fission products and one true transuranic element, today known as Neptunium. He was one of the group of physicists who were arrested when the Allied Forces entered Germany and were kept prisoners in Britain until the Spring of 1946. The group included the leading personalities of the Uranverein like Werner Heisenberg, Carl Friedrich von Weizsäcker, Karl Wirtz, and Erich Bagge. They were extremely surprised when they learned on August 6, 1945, that the first atomic bomb had been dropped on Hiroshima. Later on Weizsäcker wrote: "We, the German physicists, were mistaken about what was going on in America. We have overestimated the difficulties encountered in the production of a bomb and we have underestimated America's resources. Looking back now, our error has been, and that may well be said, of a tragic character. It is difficult to say afterwards what one would have done in a situation which never occurred."

2. A NEW BEGINNING AFTER THE BAN WAS LIFTED

During the first post-war years devastated and starving Germany had to cope with more urgent problems than that of the utilization of nuclear energy. Moreover, the allied military government of Germany had passed two acts which expressly banned the pursuit of such matters. At that time, it could not be clearly realized whether or not in the near future there would be any tendency in the world to use nuclear energy for other than military purposes. Thus, from the practical point of view, there was hardly any incentive to work at least theoretically–behind closed doors of course–on individual problems of nuclear chain reactions. All members of the former Uranverein were on the lookout for new tasks and fields of activity.

It was in 1950 that an obvious change of public feeling ran through the world. In 1950, the United States for the first time released reports on the technology of research reactors; they demonstrated the generation of electricity by means of an experimental breeder in 1951; they built the first materials testing reactor in 1952, and the first prototype of a pressurized water reactor in 1953. When President Eisenhower announced his Atom-for-Peace Program in the same year there could no longer be any doubt that the civil utilization of nuclear energy was forthcoming. In 1954 the U.S.A. even made available 100 kg. of U-235 for exportation so that smaller countries which had neither an isotope separation plant nor any fuel element production of their own were also in a position to build nuclear reactors. But it also became obvious that in addition to the U.S.A. and the U.S.S.R., Great Britain and France had equally pursued an intensive development of nuclear technology and engineering for some years.

Although Germany took the form of a Federal Republic in 1949, the Allied ban on nuclear research and nuclear engineering activities continued to have effect. On the highest political level, however, negotiations were initiated to restore full sovereignity to the Federal Republic, and it was to be hoped that on this occasion a certain alleviation of the Allied ban could be achieved. The traditional interest in nuclear research and engineering was revived in Germany little by little, and the former young people of the old Uranverein began to wonder what concrete measures should be taken to make a new beginning.

Since the Heisenberg group had originally been the leading group of the Uranverein, it was therefore Heisenberg's Max-Planck institute of Göttingen which now became the actual nucleus of German reactor development. Although the Institute had embarked on new research activities above all in astrophysics and in elementary particle physics, Karl Wirtz, the leading scientist of the last Haigerloch experiments had also founded a new field of activity there. Under his lead a new working group for reactor physics came into being at Göttingen, and the first design of an entirely German research reactor, the FR 1, was realized. Scientists even began to experiment; the produced neutron bursts in an acceleration plant and systematically pursued their behaviour in different combinations of nuclear fuel, moderators and other reactor materials, and evaluated them.

On May 5, 1955, the expected declaration of sovereignity was issued by the former occupying powers, and the Federal Republic was now officially free to engage in reactor physics and in the development of research reactors–though at first with certain restrictions. Interested German industrial firms founded the Physikalische Studiengemeinschaft for the purpose of financing the work of the Göttingen group. It was agreed to enlist the cooperation of scientists and engineers of industry in order to provide the design activities with the necessary engineering background on the one hand, but also to enable young industrial experts to become familiar with the problems of nuclear technology so that they might afterwards become the initiators of nuclear development divisions in their respective firms. The Studiengesellschaft at the same time initiated the establishment of a German nuclear research centre where the first German research reactor was to be built. Mention should be made of Karl Winnacker and Wilhelm Alexander Menne, who were the driving forces on the part of industry.

During course of these preparations – in August 1955 – the First International Conference on the Peaceful Uses of Atomic Energy took place at Geneva. Nearly all the secrecy practices which up to now had surrounded nuclear reactor development processes and applications in this field was finally abandoned and the "Promised" Land of cheap atomic current seemed to be quite near. Everywhere surges of optimism swelled up, last but not least in the Federal Republic of Germany. This enthusiasm was, however, somewhat dampened by the depressing feeling to be doomed to lag behind on account of the delayed start, a feeling which is still prevailing at the present time and to some extent unfortunately not without reason.

Though the Federal Republic of Germany was only represented by a small number of official delegates at the first Geneva Conference, the Government of Bonn took surprisingly rapid consequences from the results of the Conference. As early as October 1955, a Federal Ministry for Atomic Affairs was founded. At the same time the German Laender developed an astonishing activity and initiative in the procurement of research reactors for their universities and technical colleges. These reactors were to be put into operation as soon as possible in order to give the coming generation adequate training possibilities, and in order to make available the necessary neutron fluxes for basic research which had to be developed right from the beginning. Thus Germany deliberately decided to buy reactors abroad.

In this race of the German Laender, Bavaria was the first to reach the goal. On October 31, 1957, the swimming pool reactor of the Laboratory of Technical Physics of Munich Technical University at Garching near Munich became critical. In July, 1959, it attined full-power operation. Its thermal output amounts to 1,000 kW., and the maximum neutron flux to $1.8 \cdot 10^{13}$ n/cm.^{2} sec. The second place was taken by the Land Hessen, owing to the support rendered by its chemical industry. Farbwerke Hoechst endowed the Institute of Nuclear Physics of Frankfurt University with a homogeneous reactor having a thermal power of 50 kW. This reactor went critical on January 10, 1958. A few months later, i. e. on July 24, 1958, the Hahn-Meitner-Institut for Nuclear Research at Berlin followed with a research of the same type and power.

At the beginning of 1956 the four coastal Laender of northern Germany, i. e., Hamburg, Bremen, Schleswig-Holstein, and Lower Saxony joined to found the Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt in order to establish a research and development centre near Hamburg, at Geesthacht on the Elbe. As the title of this company suggests, there should not only be carried out the research activities of the universities and technical colleges of Kiel, Hamburg, and Hannover, but also technical and scientific development work with the aim to utilize nuclear energy for ship propulsion. For this reason a reactor of the swimming pool type having a thermal power of 5,000 kW was procured. On October 23, 1958, it attained criticality for the first time. Its flux of thermal neutrons even amounts to $3{,}2 \cdot 10^{13}$ n/cm.^{2} sec.

All the fore-mentioned reactors have a common factor in being of American origin. The Land Northrhine-Westphalia decided, however, to buy reactors of British origin, i. e. one of the MERLIN type and one of the DIDO type. Both reactors were set up in the Land research centre near Jülich to which all the universities of Northrhine-Westphalia, the universities of Bonn, Cologne, and Münster as well as the technical college of Aix-la-Chapelle, and the medical academy of Düsseldorf have access. The completion of these reators took relatively a long time, not going critical until February 23, 1962, and November 14, 1962. Their thermal output amounts to 5,000 and 10,000 kW. · MERLIN is a reactor of the swimming pool type, DIDO, however, a heavy water reactor; both use highly-enriched uranium as fuel and their thermal neutron fluxes are to $5 \cdot 10^{13}$ and/or $1{,}6 \cdot 10^{14}$ n/cm.^{2} The fact that these reactors are rather large ones, to some extent accounts for their long construction period. Moreover, the reactor DIDO was not purchased complete from Great Britain, but was built in Germany according to British designs. At least in this case the disadvantage of a long construction period could be balanced to some extent by the possibility of gaining one's own experience in the construction of reactors. The former State Secretary Leo Brandt was the driving force in the prompt setting-up of the nuclear research establishment owned by Northrhine-Westphalia.

Meanwhile, the initial Goettingen concept of building a German research reactor and making it the centre of a national laboratory like Argonne, Harwell or Saclay had been pursued. On July 19, 1956, the Kernreaktor Bau- und Betriebsgesellschaft was founded at Karlsruhe to some extent on Winnacker's initiative, with the declared purpose to obtain scientific and technical knowhow for the construction and operation of the reactor station, and to promote the practical training of young scientific and technical staff. The capital stock of this association amounted to DM 40 million, the Land Baden-Württemberg contributing 20%, the Bund 30% and Industry 50%. The FR 1 design group, headed by Karl Wirtz, was separated from the Heisenberg-Institut when this Max-Planck-Institut moved to Munich; the group went to Karlsruhe to become the parent team for our own reactor development.

In the meantime, the FR 1 design had grown into an FR 2 design, the main difference being that heavy water was to be used instead of graphite which had originally been proposed as moderator. However, natural uranium was to remain the nuclear fuel. The basic design conception of the FR 2 resembled that of the Canadian NRX reactor at Chalk River, which went critical on July 22, 1947. At Karlsruhe, however, one wanted to confine oneself to a thermal power of 12,000 kW.–compared with the 40,000 kW. of the NRX reactor; this corresponds to a reduction of the maximum thermal neutron flux from $6.8 \cdot 10^{13}$ n/cm.^{2} sec. to $3.9 \cdot 10^{13}$ n/cm.^{2} sec. Instead of the 10.5 t. of natural uranium used in the NRX, only 5 t. of nuclear fuel were envisaged for the FR 2. However, the same amount of heavy water, i. e., 18 t., were needed, the reason being that the NRX reactor is shielded by a 28 t. graphite reflector whereas heavy water is the only neutron reflector in the FR 2.

The establishment of the Karlsruhe nuclear research centre had no influence on the philosophy of work that was conceived when founding the Physikalische Studiengesellschaft. Furthermore, it was planned that young engineers and scientists of industrial firms interested in the construction of nuclear reactors and other nuclear installations should work at Karlsruhe for a certain time and then go back to their firms in order to apply the experience gained. This procedure did not always work well, since, on the one hand the companies could not wait till their people returned before realizing their projects, and, on the other hand, the guests had rapidly begun to feel at home at Karlsruhe and did not want to return. At any rate, this wish was persued with, i. e., to cooperate with Germans firms and, as far as possible, give them the opportunity to get acquainted with reactor technology. Later on, the construction of the technical components of the reactor gave rise to certain difficulties which considerably delayed starting full operation; this delay could probably have been avoided if one had fallen back on another philosophy. From the present point of view, however, the effort can be regarded a full success. When, on March 7, 1961, the FR 2 went critical for the first time, the purpose for which it had been built was largely achieved.

Since December 19, 1962, when the reactor attained full-power operation it has equally been a very valuable tool for research and development work. In addition, it has become evident today that the design was done with great precaution. As Karl Wirtz stated sometime ago in a summarizing article (Die Atomwissenschaft, April 1963), the FR 2 power tests have demonstrated "that as far as the pyrometric design of the reactor is concerned its output might easily be increased to approximately 20 to 25 MW. Cooling systems are such that the output of the reactor could be doubled to reach even 50 to 60 MW.".

Thus the thermal output of the FR 2 could equal that of the Chalk River reactor. But the reactivity reserve of the natural uranium core of the FR 2 is not large enough. As Wirtz mentions, it was thoroughly studied how such an increase in the output could possibly be achieved. The result was that a U-235 enrichment of several per cent would be required, as well as the use of uranium oxide instead of uranium metal. But it is not intended to make these changes within the near future.

Summarizing what has so far been said in this historical survey I would like to quote another paragraph from the same article by Wirtz: "As early as in 1940, Heisenberg drafted the principles of the theory of nuclear reactors in two publications which included most of the knowledge that is still valid today. Both publications, which did not take into account the development abroad, ... came to be the basis for many subcritical and exponential experiments which, during the war, were carried out on assemblies of heavy water and natural uranium (in Germany). The efforts of that time became the basis for the activities which were resumed in the Federal Republic at about 1952. Thus we may regard the Karlsruhe research reactor FR 2 the conclusion of a development commencing with the activities during the war."

3. DEVELOPMENT OF THE POWER REACTOR PROGRAMME

As is well known, the general optimism following the first Geneva Atomic Conference did not last very long. After the second United Nations Conference on the Peaceful Uses of Atomic Energy, i. e., in September 1958 at the latest, this optimism gave way to disillusionment. It was realized that investments for nuclear power stations had up to now been considerably underestimated. They were now expected to exceed the original estimates by some 50% so that the day when the utilization of nuclear energy would become competitive seemed to be postponed for 5 or perhaps even 10 years. In addition, there was the world-wide affluence of coal and therefore it was no longer convincing to argue that a primary energy gap was imminent. This tendency hardly influenced the erection of research reactors in the Federal Republic, but the German power reactor development programme suffered all the more from this world-wide change in public feeling.

After the first research reactors were ordered in summer 1956 it became obvious that the prerequisites of a promising power reactor development were not only scientific know how but also large-scale manufacturing processes with regard to materials, heat, and construction, i. e., techniques applied first and foremost in the big industrial firms which have been building conventional power stations or plants of a similar type for some time. Industry, which had already heavily contributed to the establishment of the Karlsruhe nuclear research centre urged the Atomics Minister to clearly define the competences. Finally it was agreed that training as well as scientific and technical basic research were to be the main tasks of universities and of the reactor stations financed out of public funds. Industrial reactor development, however, was to be the task of big business, interests, with all other branches of German industry participating as subcontractors.

This concept was fundamentally different from that of the U.S.A., Canada, Britain, France, and other countries of the world and which is still being followed nowadays if we think, e. g., of the Euratom ORGEL project. Development of almost every new reactor type started in a national reactor centre. It was not before the fundamental questions had been answered and the efficiency of the new type had been proved that the project was handed over to industry. From the very outset, however, the German reactor industry wanted to make its way alone. This may be due to the fact that it was feared–and not without reason–that the Government would intervene too much, but perhaps also because it was thought things would not be so difficult after all and would not cost quite so much either. Finally, this solution seemed the only alternative since obviously there was not much hope that the government would directly and completely take over the reactor development.

Very early the leading personalities of German industry clearly realized that it would be quite impossible to get along without a close harmonization and voluntary coordination of the German nuclear power station projects. The first meeting took place at Eltville on the Rhine at the turn of 1956/57; here problems were at first discussed internally and then together with the Atomics Minister; the outcome was the Eltville programme. It provided for the construction of four or five experimental power stations with an electrical output of about 100 MW. each by about 1965. Later on it therefore was often called the 500 MW. programme. Five reactor development groups of German industry were to be linked with five German energy supply companies in order to design and, if possible, also to build:

a water reactor
a gas-cooled natural uranium reactor
a gas-cooled high-temperature reactor
an organic moderated reactor
a heavy-water natural uranium reactor

The design orders placed under this programme and financially supported by the Bund were soon executed. However, it was not before the middle of 1959 and after many negotiations between the reactor development groups, the electricity supply companies, and the Atomics Ministry had taken place that a group of predominantly municipal electricity supply companies, the so-called AVR, decided to place an order for an experimental power reactor of this series. It was the pebble-bed high-temperature reactor which was designed by Rudolf Schulten of the Göttingen group, and which was based on an old American concept of Oak Ridge. In this reactor the nuclear fuel is put into graphite spheres having the size of a tennis ball. This revolutionary design permitted, if one did not want to run too heavy a risk, a construction keeping the electrical output of this experimental nuclear power station at 15 MW., corresponding to a thermal output of 49 MW. The construction order was signed on August 13, 1959, and construction started in January 1961 in the immediate vicinity of the Jülich nuclear research centre. Today, we cannot yet tell by what time the reactor will be completed since some organizational difficulties were encountered at first and some technical ones at a later stage.

Then, early in 1959, German utilities decided to place at least three definite development orders for three 100 MW. reactors of the original Eltville programme.

The following three types were under discussion:

1. A reactor with natural uranium as fuel and heavy water as moderator operating on the pressure tube principle. Heavy water, light water, light water steam, gases, organic liquids, and liquid metal were considered as coolants. The final decision was to be taken only after one year of the three years scheduled for designing had elapsed. Finally, CO_2-gas was chosen.
2. A 100 MW. nuclear or fossil fuel boiling water reactor having a 50 MW. superheater connected to it. In this case, too, a decision was to be taken only after the development had well advanced.
3. A gas-cooled natural uranium reactor of the advanced Calder Hall type. Originally a charge of fuel elements developed to various degrees was contemplated. While design work was under way, it was decided to use only a single fuel element type, i. e., enriched uranium in the form of oxide cladded by steel or beryllium. The electrical power of the reactor initially designed for 100 MW. was increased.

In addition to these three reactor types a fourth design order was placed for a 150 MW. nuclear power station having an organic moderator. This plant was to be built later under the joint Euratom/U. S. A. reactor programme. While the reactor builders were working on the 500 MW. programme, the electricity supply companies were looking for opportunities to obtain operational experience with nuclear installations as rapidly as possible. Two large German electricity supply companies, the Rheinisch-Westfälische Elektrizitätswerke AG of Essen and the Bayernwerk AG of Munich decided to build and operate jointly an experimental nuclear power station with an electrical output of 15 MW. This plant was proposed to be an American designed reactor of the boiling water type. On July 6, 1958, i. e., thirteen months before the AVR project, the building order was placed and on July 13, 1961, the power station went into operation. The plant took up full-load operation in January, 1962. The site of this first German nuclear power station is Kahl on the Main.

Soon after the development work under the 500 MW. programme had started, it was generally realized by reactor builders as well as the Atomics Ministry that planning work in Germany should take into account certain new development trends as well as any progress made at home and abroad. While the 100 MW. boiling water reactor with a superheater connected to it was developed under the 500 MW programme, it turned out that, due to the difficulties of producing nuclear superheat, it seemed advisable to carry out a special experimental reactor project. Thus in 1960 the development programme for advanced reactor types of low and medium power came into being. Since it was intended to realize construction concepts some of which were completely novel it appeared expedient to build power reactor plants of 100 MW., right from the beginning.

The following reactor types were to be developed under this programme:

1. an integrated superheat boiling water reactor of 25 MWe., now called superheat reactor;
2. a gas-cooled high-temperature reactor of the pebble-bed type with a direct-connected gas turbine, the plant having an electrical output of 5 to 10 MWe.;
3. a gas-cooled graphite moderated reactor with metal-clad fuel elements of low enrichment, and with an electrical output of 10 to 20 MW.;
4. a sodium-cooled reactor with a compact core and zirconium hydride as a moderator and an electrical output of 10 MW.;
5. a horizontal pressurized water reactor of 5 MW. electrical output.

Apart from the more conventional 500 MW. programme and this development programme for advanced reactors planning of a nuclear ship or rather a marine reactor was started in spring 1959. At one time quite a number of the most varying reactor types were under consideration. Some of the reactor types planned but rejected in this connection were included in the development programme for advanced reactors of low and medium power, for example the gas-cooled high-temperature reactor of the pebble-bed type with a direct-connected gas-turbine and the horizontal pressurized water reactor. Late in 1963 Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt decided on a pressurized water reactor of the so-called advanced design (FDR), a reactor type with integrated steam generators. The plant is said to have 10,000 to 11,000 shaft horse powers and the ship, a bulk carrier of 15,000 tdw., was launched in June 1964.

What has become of all the other reactor projects? Two of the four development orders placed under the Eltville programme in 1959/60 are awaiting construction decisions and have a good chance of being realized within short. These are the pressure tube project with CO_2 as a coolant and the boiling water project with fossil superheating. With regard to the development programme of advanced reactors the reactor having a compact core, a sodium coolant and a zirconium-hydride moderator has, up to now, been the most interesting project, and could supplement the German breeder reactor development at Karlsruhe. This project is therefore seriously discussed. The superheat reactor, too, which comes under the programme of advanced reactors and which continues the development work carried out on the boiling water reactor of the 500 MW. programme, is one of the projects the realization of which is seriously contemplated.

What has so far been said on the development of the German power reactor programme does not tell the full story, since no mention has been made of two important projects, which have even reached an advanced stage of construction, i. e., the 50 MW.(e) multi-purpose research reactor (MZFR) at Karlsruhe and the 237 MW.(e) nuclear power plant at Gundremmingen.

Development was as follows:

1. The best thing obviously was to continue the development which started with the construction of the FR 2 reactor at Karlsruhe and to build a power reactor using natural uranium oxide as a fuel, heavy water as a moderator and coolant, and being contained in a pressure vessel. After the project had been the subject of internal discussions over several years it was possible to place its building order in May 1961 and construction work was started in June 1962. This multi-purpose research reactor mentioned more than once will on the one hand be operated as a power station having an electrical net output of 50 MW. On the other hand, it is equipped with six irradiation channels to carry out loop experiments which cannot be performed anywhere else in the Federal Republic. However, the main purpose the reactor was built for, is, no doubt, to test it in continuous operation, i. e., testing various series of natural uranium fuel elements for power reactors under operational conditions and studying the behaviour of heavy water as a moderator and coolant during reactor operation. The second important purpose of this reactor is to produce plutonium of such isotopic composition as may be used later on as fissionable material in reactors, that is to say equilibrium plutonium for the coming generation of fast breeders. Strictly speaking, one should, therefore, not talk of a multi-purpose research reactor, which is its official denomination for reasons of economic policy, but of a multi-purpose reactor. The nuclear research centre of Karlsruhe offered itself as an ideal site for this MZFR reactor and thus was considerably expanded. We shall enlarge upon this at a later date.

2. The large 237 MWe. nuclear power station at Gundremmingen on the upper Danube is being built under the joint Euratom/U.S.A. nuclear power programme; thus the way taken when building the 15 MWe. nuclear power plant at Kahl is pursued; at Gundremmingen, too, the main purpose is to obtain operational experience. Again a boiling water reactor of American design is being used. Since it is realized that the development of an efficient nuclear industry at home may well benefit from reactors largely designed and also built abroad the Federal Government decided to give financial support even to such a project. This support was given above all by way of assuming the operating losses, facilitating depreciation, guaranteeing for borrowed capital, and making available money from the ERP Special Fund. The American partner granted delay of payment for the first fuel charge. Incidentally this nuclear power station is financed by the same group of electricity supply companies which operates the 15 MWe. nuclear power station at Kahl on the Main. Owing to the time limits set by the joint Euratom/U.S.A. nuclear power programme it did not take much time to

pass the building decision for this reactor in summer 1962. In late 1962 construction work was begun, and due to the rapid progress made now we may well expect this first large nuclear power station in the Federal Republic to be completed as scheduled by the end of 1965. Power production costs of this plant will presumably correspond to chose of modern coalfired power stations in the south of Germany.

After the first seven "thin" years with programmes for power reactor development being improvised, incomplete or rather restricted, it was obvious that the Federal Republic should prepare an overall programme to develop the utilization of nuclear energy which meant something like a German nuclear energy programme.

In July 1962 the then Atomics Minister Siegfried Balke asked the German Atomic Energy Advisory Committee to elaborate on such a long-term programme of assistance. Keeping in line with the five-year period of the second research programme of the European Atomic Energy Community, it should cover the years from 1963 to 1967. The German Atomic Energy Advisory Committee responded to this suggestion, and set up a special committee which began to work on October 31, 1962. This committee designated ten of its members to act as advisers, under the chairmanship of the Munich Professor Heinz Maier-Leibnitz and to draft the future German Atomic Energy Programme in January 1963. This draft was revised and amended and finally adopted by the German Atomic Energy Advisory Committee on May 4, 1963, and has since been the guide for determining the most expedient measures of promotion and planning to be taken by governmental authorities or on private initiative.

As is often the case in the field of nuclear energy utilization, the German Atomic Energy Programme, too, is different from that of most other countries. Many experts abroad have expressed fair admiration and astonishment with regard to the programme, firstly because it is so comprehensive, and secondly because it was drafted with much farsightedness.

It does not only give an analysis of the present development trends but also suggests the criteria for the future approach. The programme does not include decisions on particular projects, and thus does not run the rist of being sooner or later outdated by technical and scientific developments. On the other hand, at least in the Federal Republic itself, we cannot close our eyes to the fact that the German Atomic Energy Programme does not have the official authority as other governmental programmes of this kind usually have. Neither the Bundestag nor the Federal Government passed any resolution constituting an obligation to follow this programme during the period from 1963 to 1967. The programme is but a recommendation of the Atomics Advisory Committee which again has only advisory functions. We will still report in detail on the German Atomic Energy Programme as well as on the German Atomic Energy Advisory Committee.

4. THE BEGINNINGS OF BREEDER REACTOR DEVELOPMENT AND NUCLEAR FUSION

Attempting to get at the roots of the present development of nuclear research and nuclear technology in the Federal Republic as we do, we will soon touch upon breeder reactor development. When in the mid-1950's the first nuclear reactor of German design was conceived at Göttingen, the remote aim was to develop it into a breeder or at least a converter. It was not only with a view to obtaining a good neutron economy which is the prerequisite for a high conversion rate that graphite–used as a moderator in the FR 1–was exchanged for heavy water to serve as a moderator and reflector in the FR 2. At first thermal breeding was under consideration, i. e., a thorium-uranium cycle. In former descriptions of the FR 2 the information is contained that apart from 6 t. of natural uranium the fuel charge will consist of 1 t. of thorium. At present the FR 2 is operated with only 5 t. of natural uranium and the development of a thermal breeder which was originally proposed by Karlsruhe has meanwhile shifted to Jülich, where a similar programme is under way in connection with the high-temperature pebble-bed reactor and where it is planned to develop a large prototype breeder reactor of 500 MW. (thermal) on a thorium basis.

At Karlsruhe, however, activities concentrated on the fast plutonium breeder reactor. After physical design work on the FR 2 had almost been completed by 1957, a seminar on fast breeders was held at the Institute of Neutron Physics and Reactor Technology of the Karlsruhe nuclear research centre during the winter term of 1957/58. The aim was to find new trends for the work of the institute after completion of the FR 2. When planning and design work on the FR 2 had finally been concluded in spring 1960, a large study group was preparing to take charge of the development of a breeder reactor and thus Karlsruhe "fast breeder" project took definite shape. Today, the project is headed by Wolf Häfele, and the work is no longer limited to one particular institute of the Karlsruhe centre but has become its main effort. For the time being about 200 university-trained scientists and engineers are working for this project.

Under this project fundamental experiments in the reactor physics, engineering and technology field will be carried out in order to obtain, by 1967, the parameters for a prototype power reactor to be built by 1972. To this end, construction of several experimental facilities was started, and an association contract concluded with the European Atomic Energy Community. In spring 1964 successful negotiations were concluded on the participation of the Karlsruhe group in the American SEFOR project including the construction of a fast dynamic test reactor with some type of plutonium fuel in the State of Arkansas.

If the first Geneva Atomics Conference of 1955 was a great revelation for reactor designer, the second Geneva Atomics Conference of 1958 meant the breakthrough in fusion research. After British scientists had ventured forth and shown their ZETA machine to the press, all information on experiments to obtain controlled nuclear fusion, fusion research or plasma physics, which is its modern and more correct name, which up to that time had generally been classified, was de-classified. This time the German teams of scientists were better prepared than their colleagues of reactor engineering in 1955 and during the General Session on the Possibility of Controlled Fusion a summarizing report was given on German activities in this field, the only German paper to be presented in a General Session.

Thus, in 1956, a special working group was set up at the astrophysical division of the Max-Planck-Institut of Göttingen, and, on the basis of previous astrophysical applications of plasma physics the work of this group was then devoted to theoretical investigations of the problem of controlled thermo-nuclear fusion. In addition an experimental division for plasma physics was set up. At the physical institute of Aachen Technical University a study group was also formed in 1956 with the aim of performing research work on the physics of high-temperature plasmas.

Similar activities were taken up at the Stuttgart Technical University in 1956 and a special working group of the laboratory for technical physics of Munich Technical University had started to investigate the problems of plasma physics. It goes without saying that the Geneva Conference of 1958 did much to stimulate the work of these research groups. They were now able to step out of their isolation and to get into contact with foreign study groups whose work had followed similar lines–last but not least they could judge their own work and compare it with international standards. The results of the Geneva Conference were disappointing for those who had hoped to find a rapid solution to fusion research problems by a stroke of genius. The results also revealed that a lot of basic research remained to be done and that the lead of the U. S. A. and other countries was obviously not so significant as to paralyze the German efforts. Therefore plasma physics was given special assistance in the Federal Republic.

In 1960 the Institute of Plasma Physics was founded as a GmbH (company with limited liability) in Munich. It was given its own legal status within the Max Planck Society and was housed in the immediate vicinity of Munich Technical University at Garching. More than 500 people are employed there today and work on the third construction phase of this large group of institutes has started. This new institute is now carrying on the work formerly done by Munich Technical University and to quite an extent, that done by the Max-Planck-Institut for physics and astro-physics which was moved from Göttingen to Munich in 1958.

At the same time the working groups of the physics institute of Aachen Technical University gradually became the institute for plasma physics of the Jülich nuclear research establishment; today, 120 people work in this institute. The activities at Stuttgart led to the formation of a working team which on January 1, 1961, was made a regular new institute of Stuttgart Technical University.

With regard to the development of high-energy physics montion should be made in this historical survey of the "Deutsches Elektronen-Synchrotron" (DESY) (German electron synchrotron), a cyclic accelerator for electrons of up to 6 Bev (billion electron volt). In 1957, work on the construction of this DM 85 million project was started and in late February 1964 the accelerator went into operation without any major difficulties. Thus, expenditures on high-energy physics in Germany are not of the order of magnitude of British, French, and Italian expenditures but plans for a German proton accelerator have seriously been discussed, so that in this field, too, we will soon have attained international standards.

These remarks conclude this historical survey–which, I am sure, is not complete. It was natural that technical particulars had to play a minor part in this context. In the following chapters the individual projects will be dealt with more thoroughly and at greater length. Moreover, we should always bear in mind that the nuclear energy development of a country is a very complex thing with many sides to it. In whatever way we look at it we shall discover only one aspect at a time.

III. WHO DETERMINES GERMANY'S ATOMIC POLICY?

Organizational Framework

Whoever intends to visit an exhibition should first of all consult a guide for getting familiar with the exhibition's layout. Accordingly it seems to be expedient to begin the description of the present state of nuclear research and nuclear engineering in the Federal Republic of Germany with a survey of the organizational setup within which these activities are carried out.

1. GERMAN ATOMIC ENERGY ADVISORY COMMITTEE

As is probably the case everywhere else in the world–at least to a varying degree–there are above all three sources in the German Federal Republic, feeding the activities for the utilization of nuclear energy, namely:

1. research,
2. private enterprise initiative,
3. the government's efforts to guarantee the continuance of the country's sound economic development.

In this connection it is quite obvious that there are close interrelations between these three sources. In the Federal Republic of Germany, however, these interconnections are cemented in the organization, i. e., by the Deutsche Atomkommission (German Atomic Advisory Committee).

The German name undoubtedly is somewhat misleading for a foreigner and above all for an American, since it is not an organization similar to the U.S. Atomic Energy Commission, but rather a body that is termed a board or a committee in anglo-saxon language usage. The Deutsche Atomkommission is merely an advisory body for the Federal Government, or strictly speaking, to the Federal Ministry for Scientific Research. The German Atomic Energy Advisory Committee has no official powers to take decisions or to discharge any functions nor is it responsible to parliament. Still, its recommendations carry great moral weight since the Committee includes all the competent experts from research and industry. Therefore, the Federal Ministry for Scientific Research will, in general, not act contrary to a decision taken by the Atomic Energy Advisory Committee but will, as a rule, try to realize the Committee's recommendations.

Apart from this direct advisory function the German Atomic Energy Advisory Committee is the ideal platform for experts to have internal discussions on programmes, individual projects, and proposals regarding the granting of budgetary means prior to discussion of such matters before parliament and in public. The former Federal Minister of Nuclear Energy, Siegfried Balke, characterized the importance of the German Atomic Energy Advisory Committee as follows: "Today, public administration–even if it includes a number of outstanding experts–is no longer in a position to cope with the tasks assigned to it by Government and Parliament with its own officials only. It has to rely on the advice of experts from science, technology, and economy. For quite sometime we have been considering in which way public administration could make use of the expert knowledge of scientists, technicians, and economists. The establishment of the German Atomic Energy Advisory Committee has been an effort to this effect. It comprises 27 well-known and influential personalities of science and economy as well as of public life. They have, however, not been selected for this committee to represent the interests of associations or consortiums or firms but on account of their expert knowledge and experience which alone give weight to the decisions and recommendations of the German Atomic Energy Advisory Committee."

In order to fulfil its advisory duties with the necessary expert competence the original Atomic Energy Advisory Committee set up five expert committees, themselves divided into 16 working groups. These bodies comprise a total of approximately 220 members. For a comparison it may be noted that this number almost exactly corresponds to the number of personnel in the Federal Ministry for Scientific Research as far as it is concerned with nuclear energy matters. Up to December 31, 1963, the German Atomic Energy Committee, its expert committees and working groups held 420 meetings in all equally distributed over the years. This number does not include the activities of special committees formed within the Committee for special tasks, for instance for the elaboration and formulation of the mentioned German Atomic Energy Programme. Moreover, it is possible to discuss in detail, within the Committee and its working groups, individual subjects on an ad hoc basis by consulting guests as well as by referring to opinions of individual experts or groups of experts. The former Atomics Minister, Professor Balke, was certainly not exaggerating when stating that his Ministry was able to get along with a relatively small number of personnel due to the assistance of a great number of outstanding experts of the Atomic Energy Advisory Committee. These personalities, it is true, place at the Ministry's disposal their knowledge and experience gained in top positions in science and economy without claiming any financial reimbursement.

The structure of the German Atomic Energy Advisory Committee and its expert committees and working groups-shown in the appendix to this report-demonstrates the wide range of their activities. Such activities extend from nuclear legislation to radiation protection, from nuclear chemistry and nuclear physics to nuclear reactors, and from radiation biology to training problems. The legal basis for the activities of the German Atomic Energy Advisory Committee is a decision of the Federal Government of December 21, 1955.

2. THE FEDERAL MINISTRY FOR SCIENTIFIC RESEARCH AND ITS PARTNERS

As mentioned earlier, the present Ministry for Scientific Research is more or less the successor of the former Ministry of Nuclear Energy. After its establishment in 1955 the latter was first called "Federal Ministry for Atomic Affairs". In October, 1957, its title changed to "Federal Ministry of Nuclear Energy and Water Economy". Finally in December, 1962, the Ministry's functions were expanded and it was then called Federal Ministry for Scientific Research. It now comprises three fields of activity, namely "general science promotion on the one hand and the special fields–nuclear energy and space research–on the other".

By this formula, taken literally from the Federal Ministry's annual report of 1963, it becomes quite obvious that a change of emphasis has taken place since nuclear energy, so far the main point of activity of the Ministry has become a special field of general science promotion. Though this change is deplored by many people in Germany it cannot, however, be denied that this development has a very positive aspect, too. The original mandate of the Atomics Ministry read as follows: "to handle centrally all matters related to the exploration and utilization of nuclear energy for peaceful purposes on consultation with the other Federal Ministries concerned." Although it did not always become evident to the public the Atomics Ministry has never been more than the "centrally handling authority" as soon as the competence of other ministries became involved such as that of the Federal Ministry of the Interior with regard to general science promotion. By assigning these functions to the Research Ministry some rather important points of friction were eliminated. Details of this Ministry's organization and the internal distribution of functions may be seen from the organization chart contained in the appendix to this report.

But a democratic system of government should not only have an executive but also an adequate legislative. This means: In addition to the Ministry for Scientific Research and its Atomic Energy Advisory Committee there should be a Bundestag committee whose members, too, are experts or who calls upon experts. Indeed, there is a Committee for Nuclear Energy Affairs in the German Bundestag. It comprises members of parliament who have been familiar with atomic affairs for many years, and certainly one cannot even complain about bad co-operation between the Ministry for Scientific Research and this committee of the Bundestag. And yet, what the public and occasionally farsighted personalities of nuclear research and atomic industry demand is a parliamentary institution that, due to its expert knowledge, would be capable of developing its own initiative with regard to atomic policy matters so as to expand and supplement the Ministry's policy. In this context, the Joint Committee on Atomic Energy of Washington with its famous "202-Hearings" could more or less be regarded as a model though it is being criticized by many people in the U.S.A. Not only in the Federal Republic of Germany but nearly everywhere in the industrialized countries of the free world we observe that parliamentary control of government is getting more difficult to the extent that government has to sponsor technically and scientifically complicated developments. To actually realize this danger is the first step to banish it.

The organizational framework of German nuclear research in the narrower sense is given by the research institutes of colleges and universities, the Max-Planck-Institut, the scientific institutes of the large national research centres, and to some extent also by the research establishments of the Bund and the Laender and finally by the research institutes of industry. The Max-Planck-Institut are able to carry out more comprehensive research activities without the burden of lecturing commitments, but often, however, without any direct contact to young blood of the universities. In fact, the Max Planck Society is a research institution for which the Federal Republic of Germany is envied by many other countries. This, however, does not exclude the fact that there are some people even in the Max Planck Society who occasionally advocate an orientation towards big science, thus going back to the original aims of the Kaiser-Wilhelm-Institut, the predecessors of the Max-Planck-Institut. At that time it was important to enable new research institutions for which there was no room at the existing colleges and universities to develop capacity. These are nowadays the "Projektwissenschaften", a term coined by Wolf Häfele to describe what is meant by "big science". The Institute for Plasmaphysik at Garching near Munich, a recent foundation of 1960 within the association of institutes of the Max Planck Society, is a first step towards this aim.

3. THE GERMAN ATOMIC FORUM

When considering the organizational framework of nuclear energy development in the Federal Republic mention has to be made of the Deutsches Atomforum (German Atomic Forum). It comprises the leading personalities of industry as far as they are interested in the development of nuclear energy. But it is much more than a body representing the interests of industry. Well-known members of parliament are on its Presiding Board. Moreover, the German Atomic Forum is, above all, concerned with public relations work. It organizes scientific symposia, seminars for journalists, information weeks for the public, and mobile exhibitions. When, for instance, during the establishment of the Karlsruhe Nuclear Research Centre a substantial psychological resistance had to be overcome on the part of the population in the immediate neighbourhood who were afraid of "nuclear damage"–the Centre is not situated on the territory of Karlsruhe itself, but north of it, i. e., in the municipality of Leopoldshafen–it was above all due to the public relations work of the German Atomic Forum that finally a more realistical approach was taken to the alleged dangers. The German Atomic Forum to which nearly all associations and institutions of the natural sciences, of engineering and science are affiliated also endeavours to advance scientific work and research within its own rank. According to a statement of its President, Professor Karl Winnacker, it attempts, and very much so, "with the active assistance of its numerous members sitting in parliamentary and legislative bodies, to win goodwill and understanding for the great and economic aim".

Attempting to describe in the following chapters the present state of development of nuclear energy and technology in the German Federal Republic we are confronted with the problem to create an order which actually does not exist, since the boundaries are not clearly marked out. You can hardly describe a certain reactor project without mentioning the research centre or the firm tackling this project. And vice versa, it is hardly possible to disregard the reactor development when describing a large research centre. Thus the chapters "research centres" and "reactor development" will naturally overlap to some extent. Moreover, for the sake of charity, an occasional reference to the already described historical development cannot be avoided.

IV. RESEARCH CENTRES AND THEIR PROJECTS

A Survey of Governmental Activity

46 The director of the Oak Ridge National Laboratory, Mr. Alvin M. Weinberg, highly estimated in Germany on account of his critical analyses, once said that in the history of mankind there have always been some reifications of a certain spirit of the respective age, which cannot be motivated rationally. When the Egyptian civilization was at its peak people built pyramids; in the Middle Ages they built magnificent cathedrals, and during the past centuries of modern times big castles. Today, we seem to have the nuclear energy plants and rocket stations which demonstrate the will and skill of our modern industrial society.–“What path is it we are following and which is expressed by such enumerations?” asked Wolf Häfele of Karlsruhe during his lecture at Loccum.

1. THE KARLSRUHE NUCLEAR RESEARCH CENTRE

The place in the Federal Republic of Germany to which these ideas apply best, is situated in the so-called Hardtwald, i. e., 12 km. north of Karlsruhe. It is the Karlsruhe nuclear research centre in which DM 300 million have so far been invested and with regard to which decisions on further constructions have been taken carrying the investments to a total of some DM 700 million. Whoever visits the Karlsruhe nuclear research centre today can hardly imagine that 8 years ago when the Kernreaktor Bau- und Betriebsgesellschaft came into existence one bargained whether or not an original capital of DM 38 million instead of the proposed DM 40 million would do. 50 per cent of this amount was raised by German industry, 30 per cent by the Bund, and 20 per cent by the Land Baden-Württemberg.

The capital was soon after increased to DM 60 million, the participation of German industry remaining at 50 per cent. But already in summer 1959, it was necessary to found a second sponsoring company in which the Bund had a 75 per cent share and the Land of Baden-Württemberg one of 25 per cent. In the meantime, both companies were merged into "Gesellschaft für Kernforschung" which is sponsored by the Bund as well as by the Land Baden-Württemberg. German industry gave its own share of DM 30 million to this new company as a true gift. At present some 2,500 people are employed at the centre; this number, which will increase to 3,000, does not include, however, the personnel required for the multi-purpose reactor, the European Transuranium Institute, and the compact sodium-cooled nuclear reactor which is still under discussion, whether this centre–like nearly all other large research and development centres–will ever be completed.

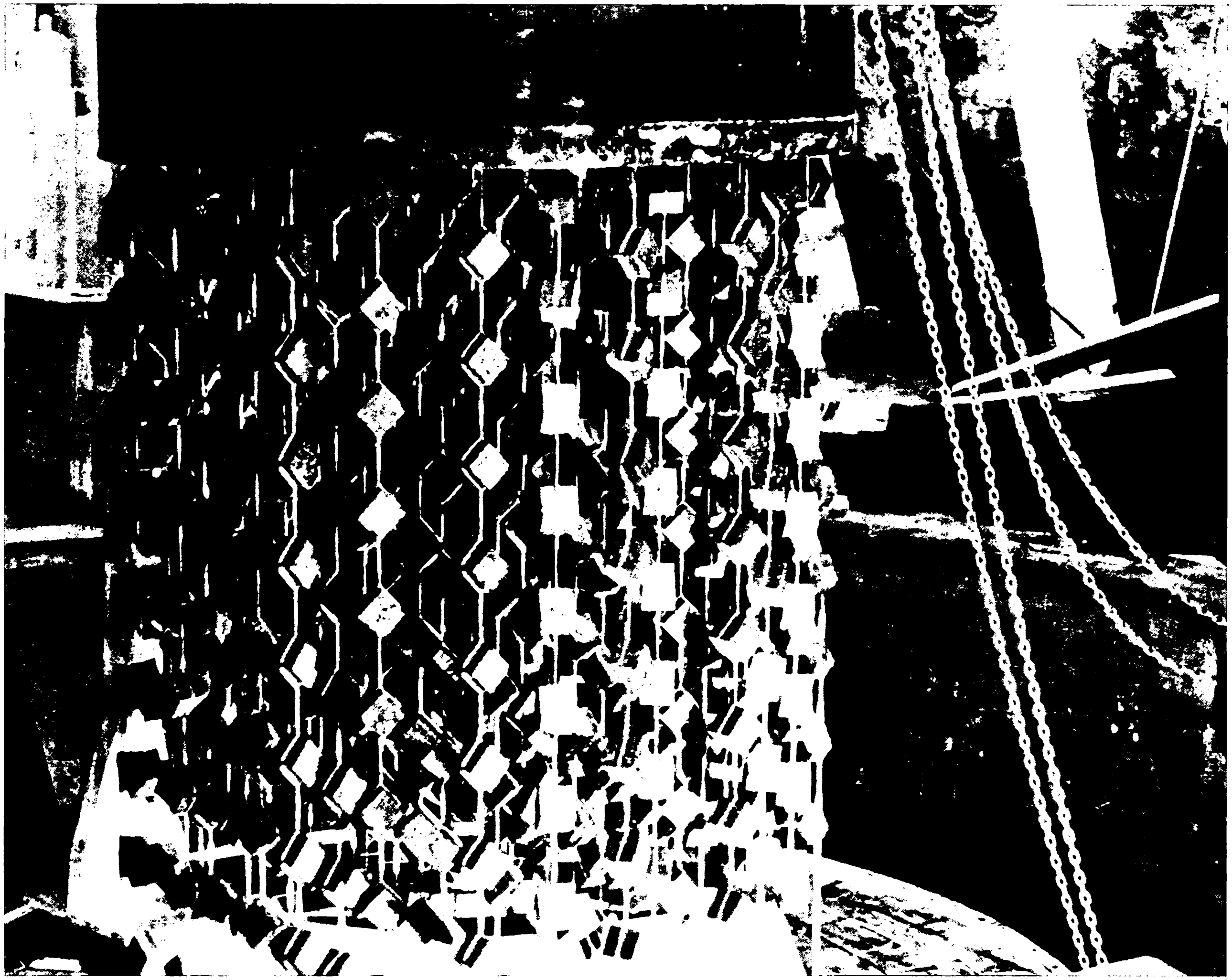
a) Reactors

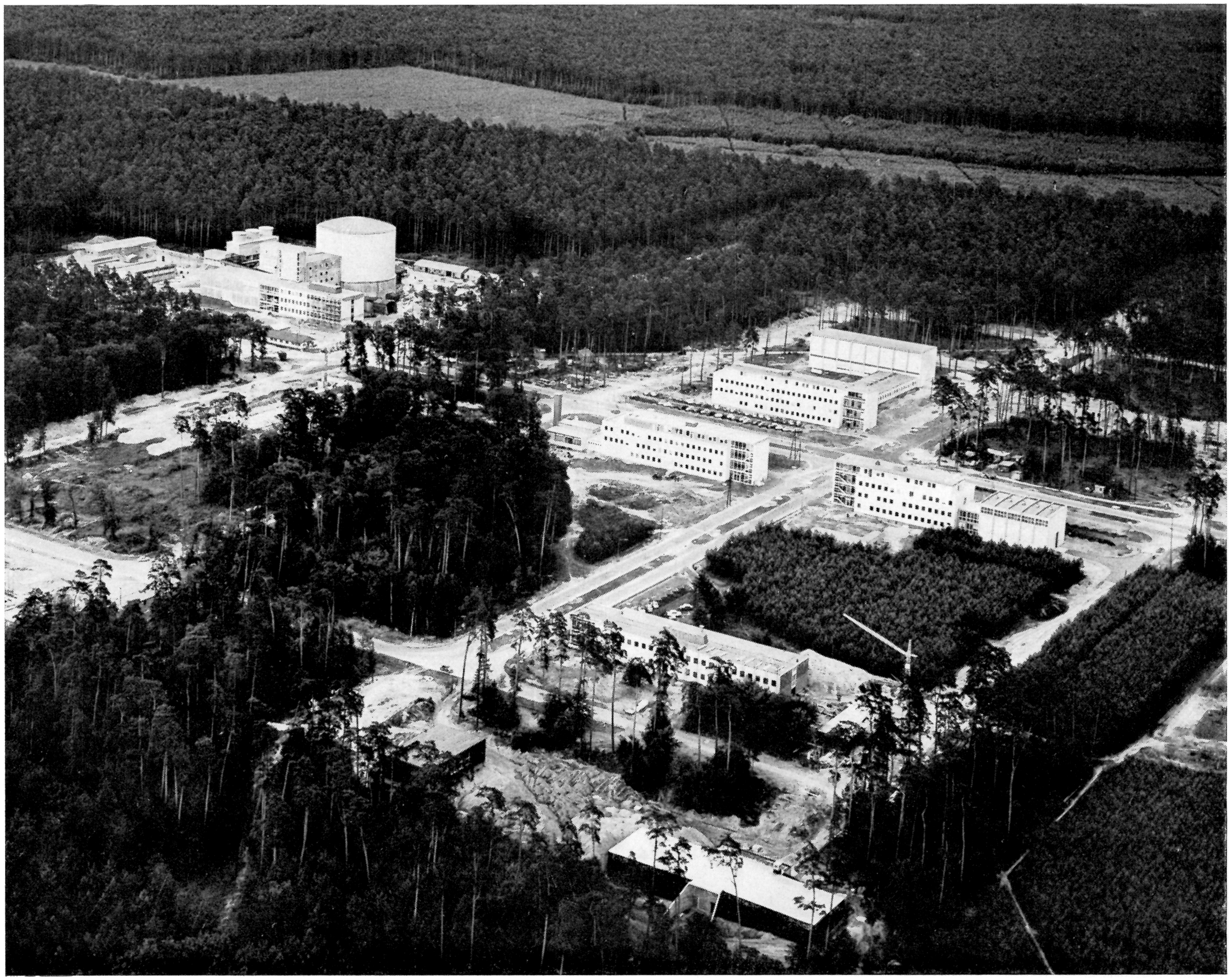
In spite of all the construction activities under way the main part of the Karlsruhe centre is still the FR 2 research reactor, the development of which has already been described in detail. This reactor is equipped with a number of differently arranged experimental channels. Three vertical channels are used mainly to test fuel elements. Samples may be inserted into the reactor or into the core for irradiation purposes, or neutrons may be extracted from the reactor for experiments by means of 13 horizontal channels of different diameters. Moreover, a thermal column consisting of 6 vertical and 6 horizontal experimental channels lends itself for experiments with thermal neutrons. Capsules for isotope production may be inserted into the core at 41 different spots. Since spring 1963 the FR 2 is in full operation and its radiation channels are steadily occupied. With a view to exploit the reactor even more rationally, an engineering hall is being built where assembling and mechanical testing of experimental installations can be carried out without impeding reactor operation. Moreover, serious consideration is being given to increase the output of the reactor. The reactivity reserve of the natural uranium core will be sufficient only to a certain extent, and later it may probably be necessary to change from uranium metal to uranium oxide and to obtain a U-235 enrichment of some per cents. However, it is not intended to bring about these changes in the near future.

Apart from the FR 2, the nuclear research centre possesses a further small reactor of the ARGONAUT type. This famous reactor, characterized by its ring-shaped core, was developed by the Argonne National Laboratory in the United States first and foremost for training purposes. However, only its basic concept was adopted. The detailed design and construction work was done by German firms. The tasks for which the ARGONAUT reactor of Karlsruhe was originally built were training and demonstration. But soon after it was taken into operation in January 1963, the reactor was remodelled. It was equipped with a central reactor core for fast neutrons. We shall deal with this subject at greater length under the Karlsruhe fast breeder project.– It may be mentioned in this context that the Karlsruhe ARGONAUT reactor is the third reactor of its type in Germany. Both AEG and Siemens-Schuckertwerke AG set up an ARGONAUT reactor each for their respective reactor divisions. These reactors are located in the research and development laboratories of the two companies, i. e., Großwelzheim near Frankfurt (AEG) and Garching near Munich (SSW). The third large reactor project under construction at the Karlsruhe Nuclear Research Centre is the multi-purpose reactor which continues the FR 2 development. As mentioned, it shall not be used primarily for pure research, but will help to solve problems ranging from applied research and important development problems right down to the testing of a complete power reactor under actual nuclear power plant conditions. Perhaps it is best described as a combination of a test reactor and a prototype nuclear power plant. Due to the fact that this reactor achieves an net electrical output of 50 MW., it is capable of bearing a substantial part of the operational costs itself.

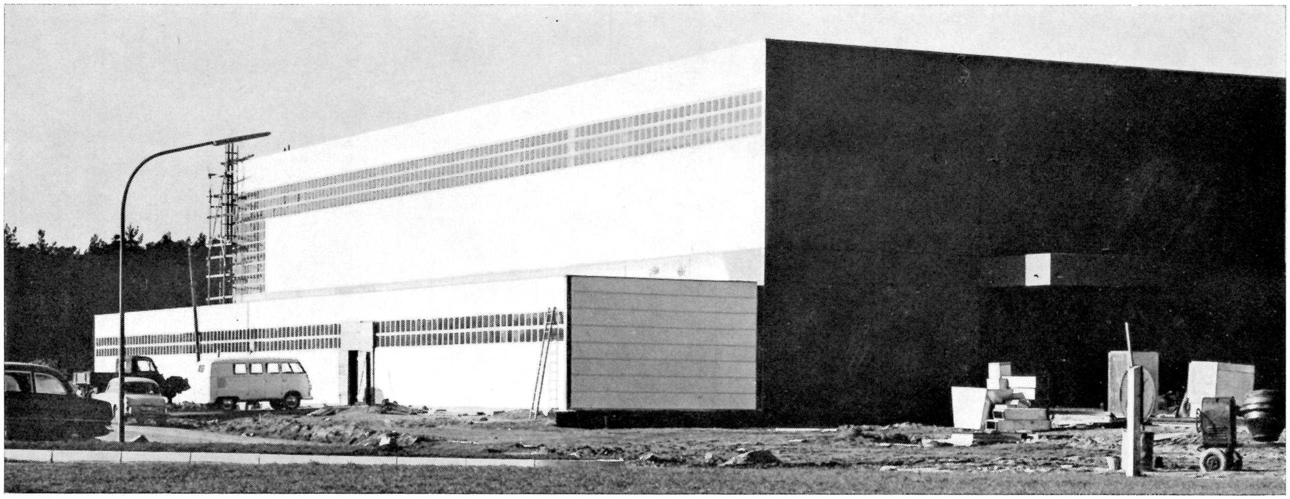
The pressure vessel of the multi-purpose reactor has an inner diameter of 4.1 m, and in this vessel a second, so-called moderator vessel is suspended. The latter is traversed by 121 vertical hot channels which, at the top and bottom, run into inlet and outlet chambers. Those channels which are inside the core are made of zircaloy, those outside the vessel are made of steel. Apart from conducting the fuel elements a thermal separation of the D_2O coolant from the D_2O moderator is, at least to some extent, made possible by this kind of moderator vessel. This was achieved by realizing a novel design concept: control of the reactor's output

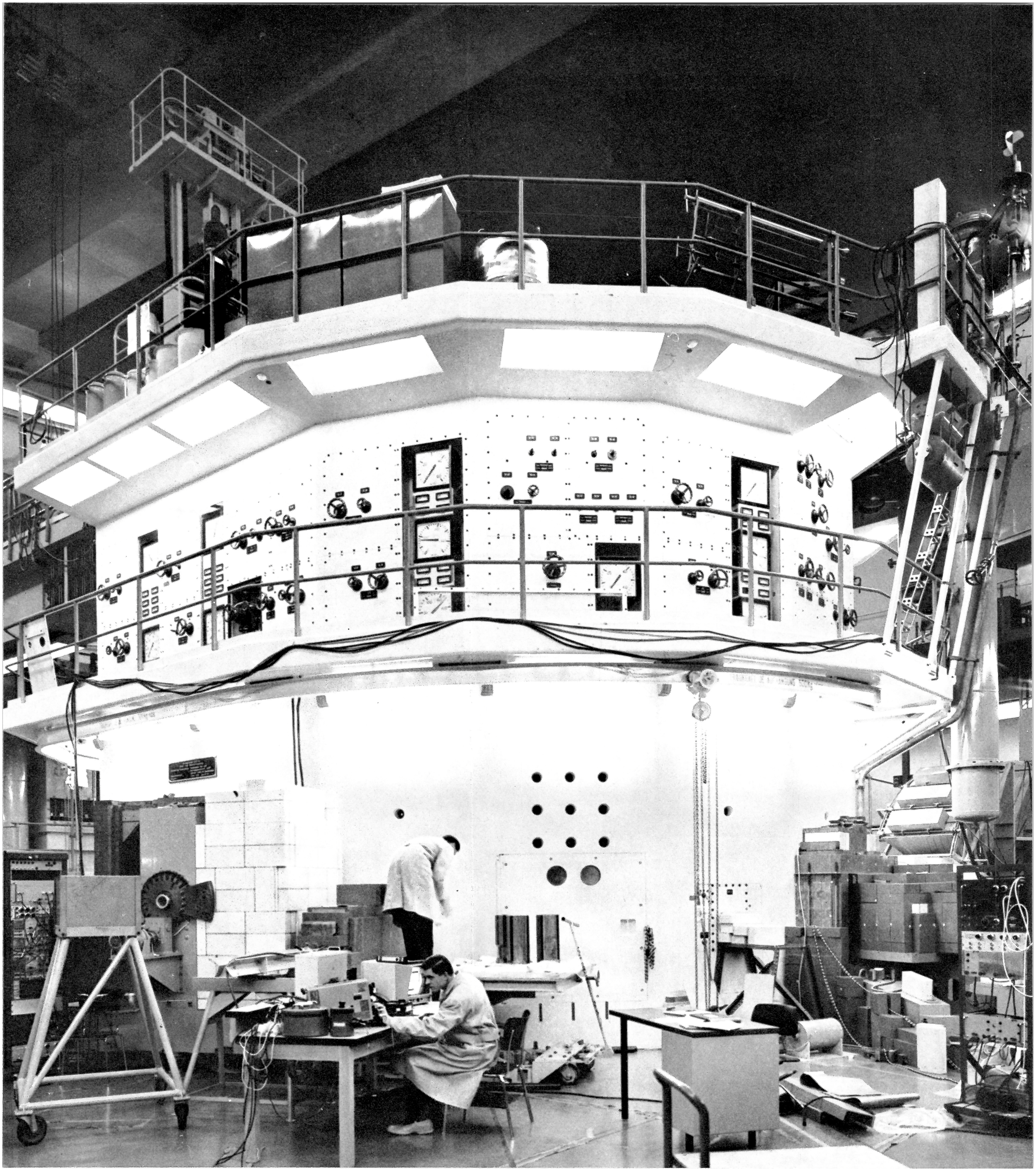
In the winter of 1944/45 a last German effort was made to set a reactor assembly going by concentrating all supplies of uranium and heavy water in a vault at Haigerloch. An amateur photo (below) of that time shows the network of uranium cubes which suspend from thin wires and which were lowered into a cylindrical reactor vessel filled with heavy water and surrounded by a graphite reflector. However, criticality of this assembly was no more achieved.



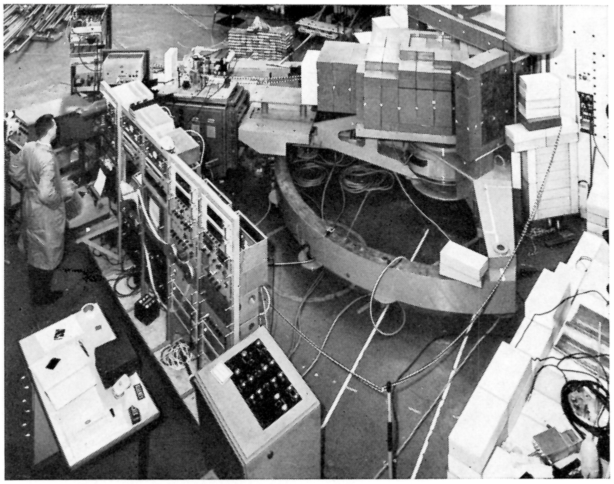


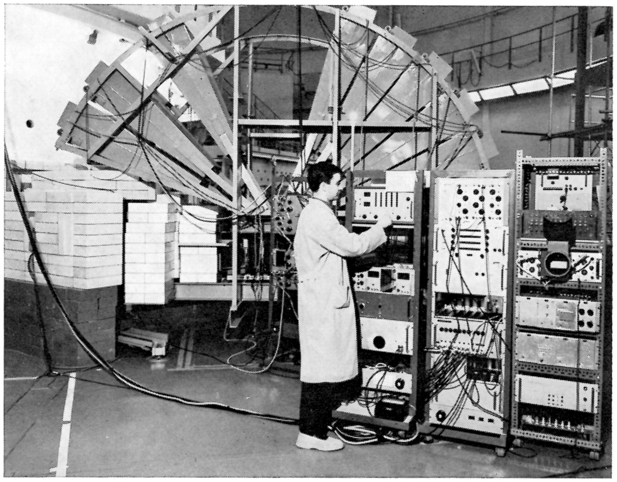
The first nuclear research reactor of German design was built in a forest area north of Karlsruhe after the ban on nuclear research was lifted in 1955 and came to be the pivotal point of a large nuclear research centre. In the upper corner of the aerial photo (left) taken in 1960 you will see the reactor hall of the FR-2 and some institutes. Photos on this page were taken in 1964; above: the building for the hot cells which is nearing completion, below: two wings of the European Transuranium Institute which have just been completed.

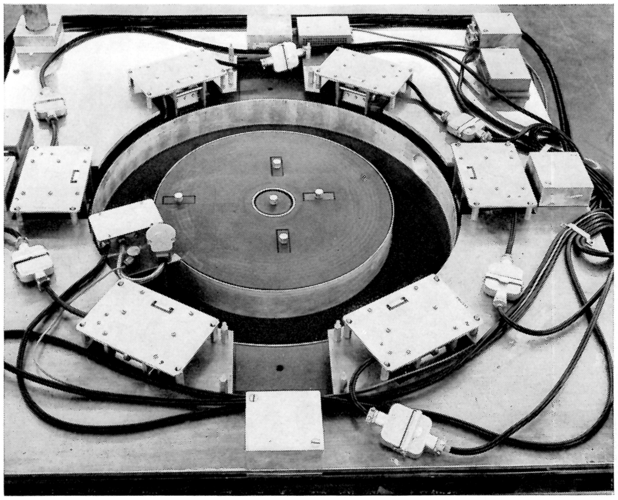


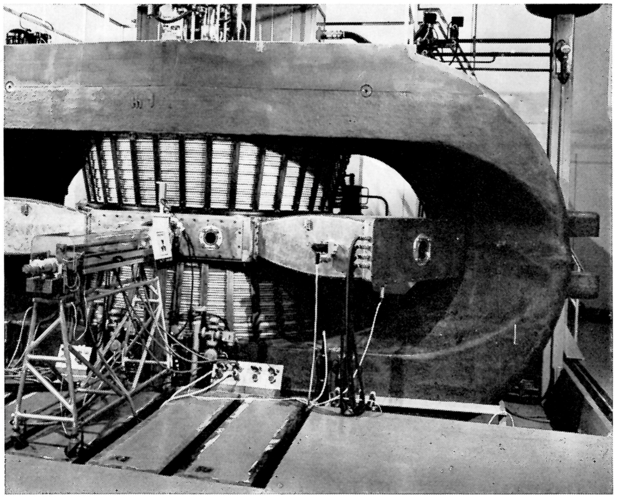


With a thermal output of 12,000 kW, 13 horizontal beam holes and a thermal column the heavy-water natural uranium reactor FR-2 at Karlsruhe is a very efficient research tool. On the left: an overall view of the reactor with some of the experimental facilities attached to it; in the upper left of this page there is a large precision crystal spectrometer for cross-section measurements; on the right: irradiation experiments using a television camera, and below: a novel rotating crystal spectrometer.

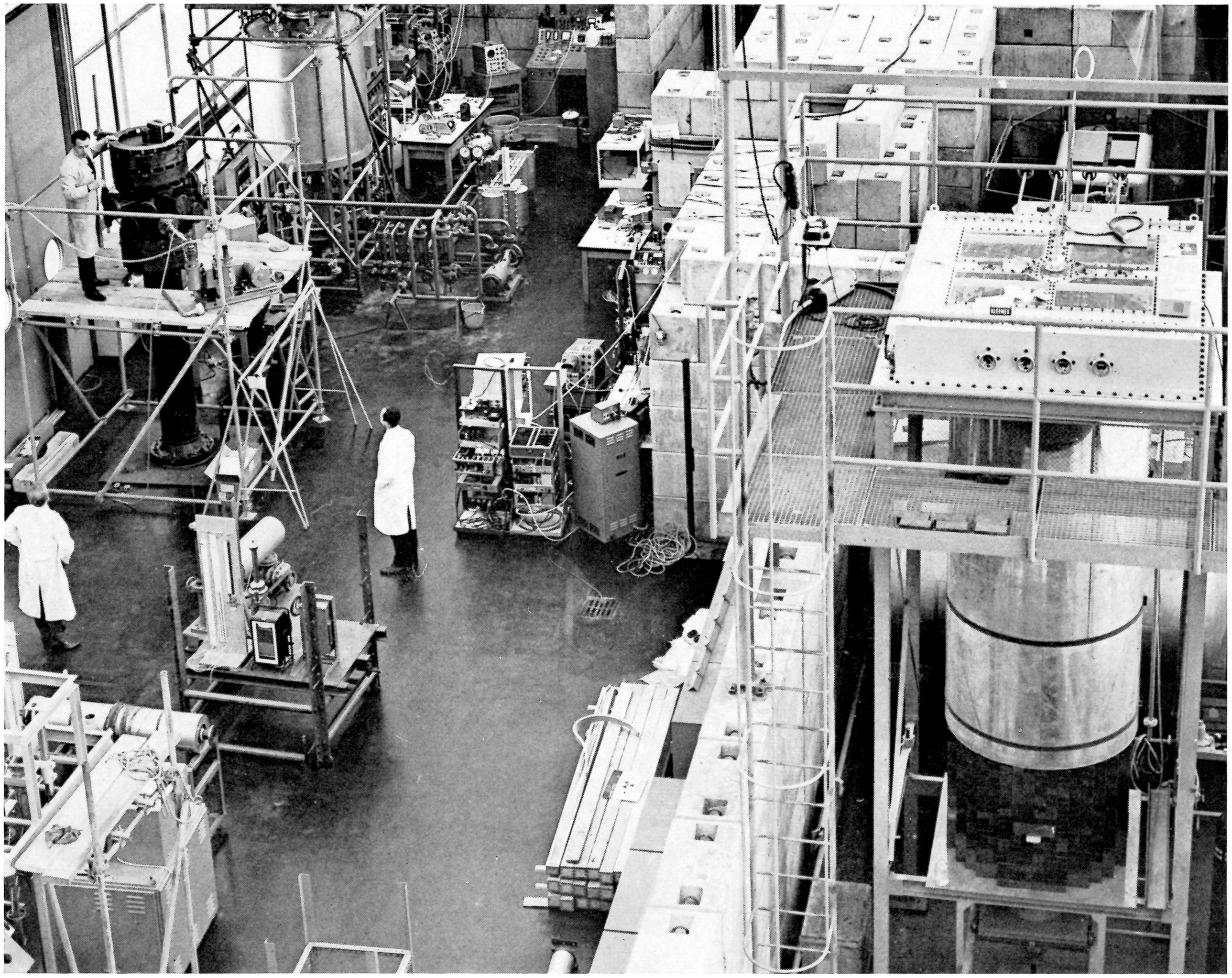




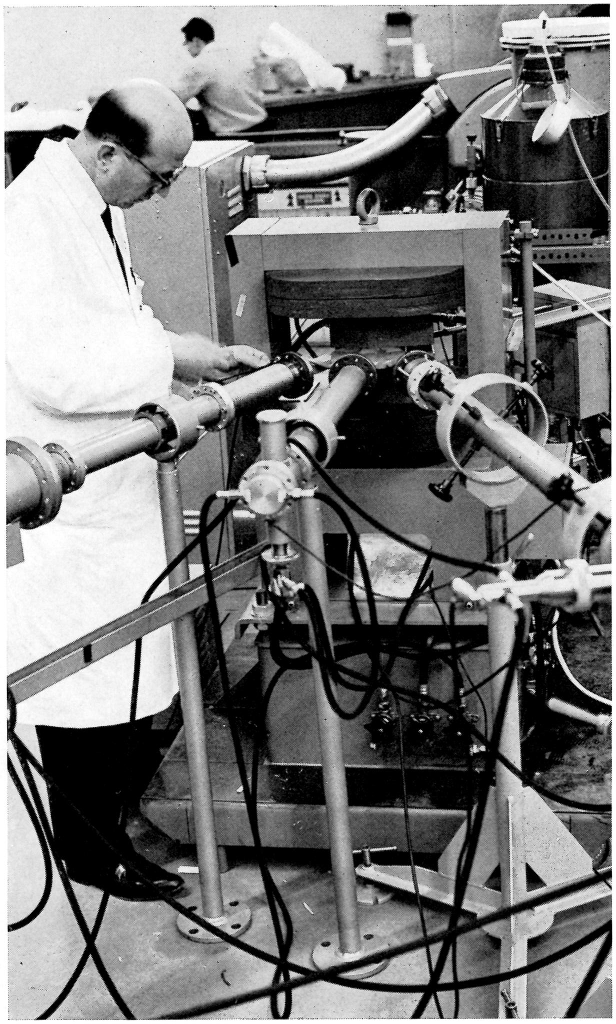


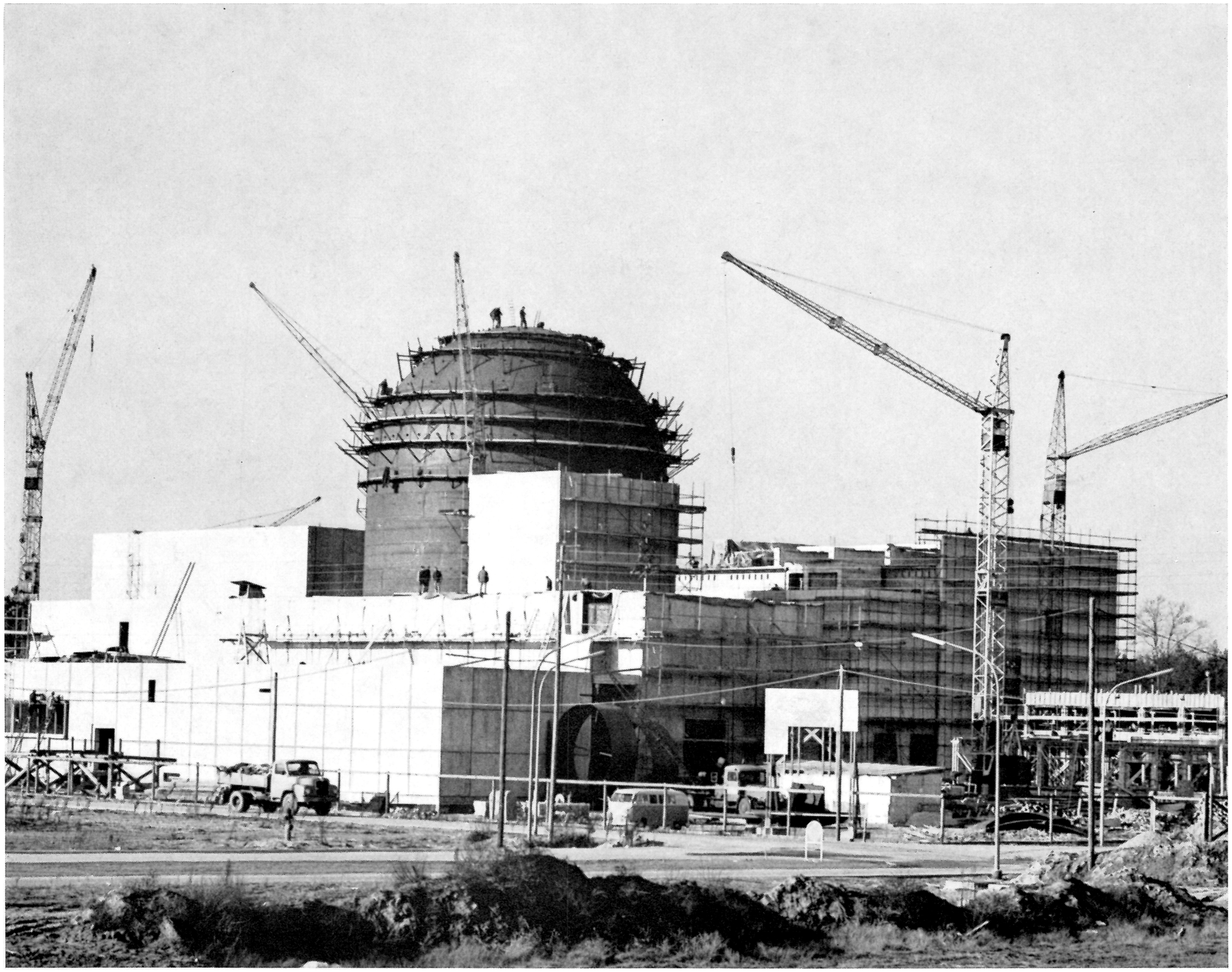


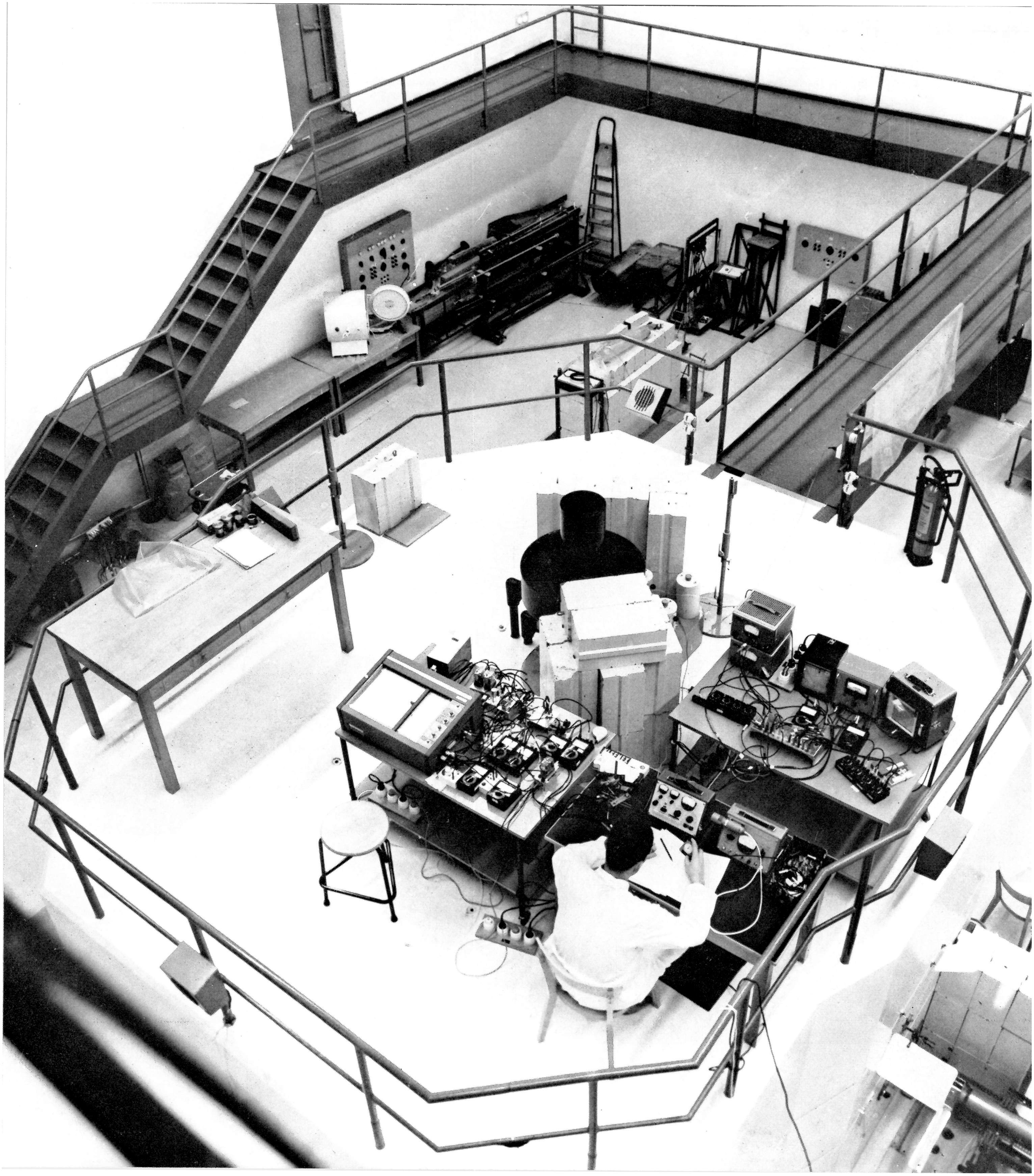
In addition to the FR-2 the Karlsruhe Nuclear Research Centre today disposes of quite a number of other experimental facilities. On the upper left side: a view of the core of the Karlsruhe Argonaut-type reactor. In the meantime the central graphite core was replaced by a fast subcritical core. On the upper right: the isochronous cyclotron accelerating deuterons to 50 MeV. On the opposite page: a view of the large experimentation hall of the Institute of Neutron Physics and Reactor Physics.



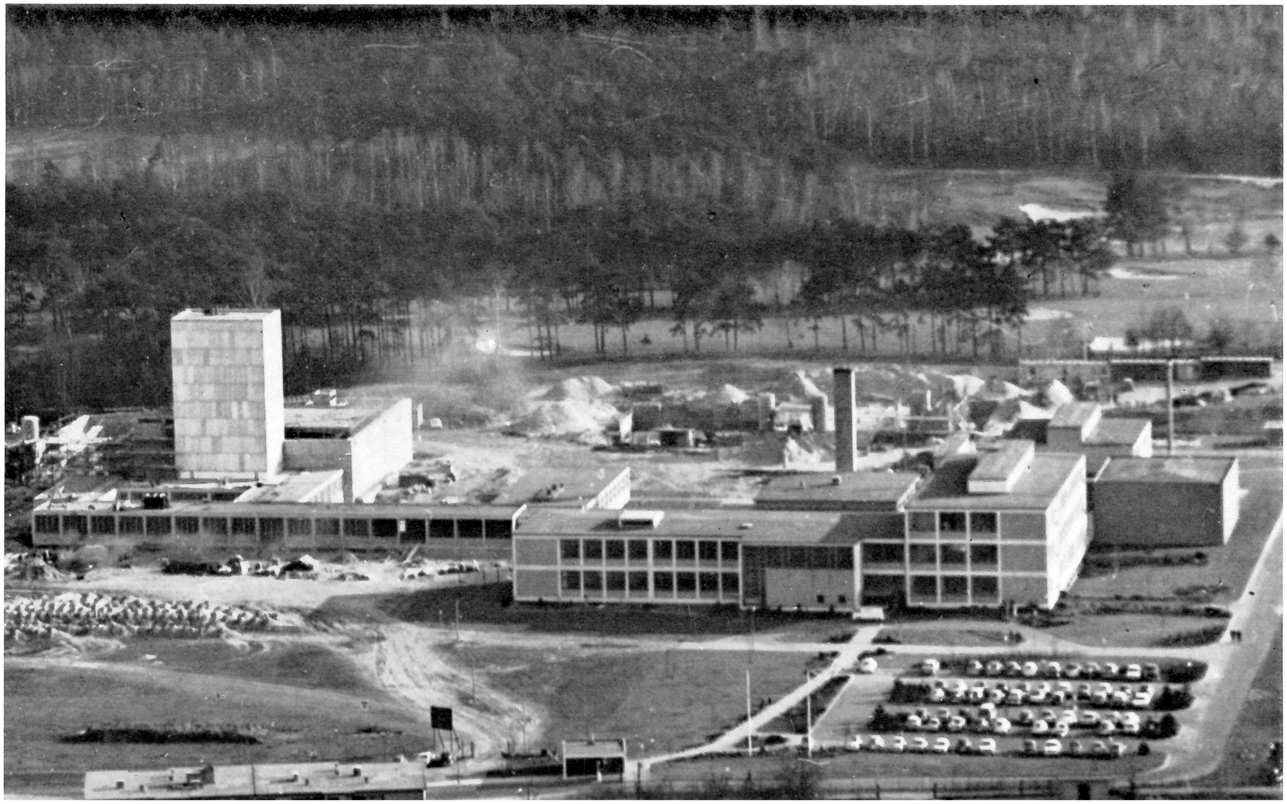
The experimental technique developed in Germany during the war and used to study neutron pulses in subcritical assemblies is still being applied at Karlsruhe. Below on the left: a picture of a pulsed assembly for the measurement of neutron spectra, next to it on the right: a Van-de-Graaff accelerator. The picture on the opposite page shows the multi-purpose reactor under construction at the Karlsruhe Nuclear Research Centre in summer 1964.

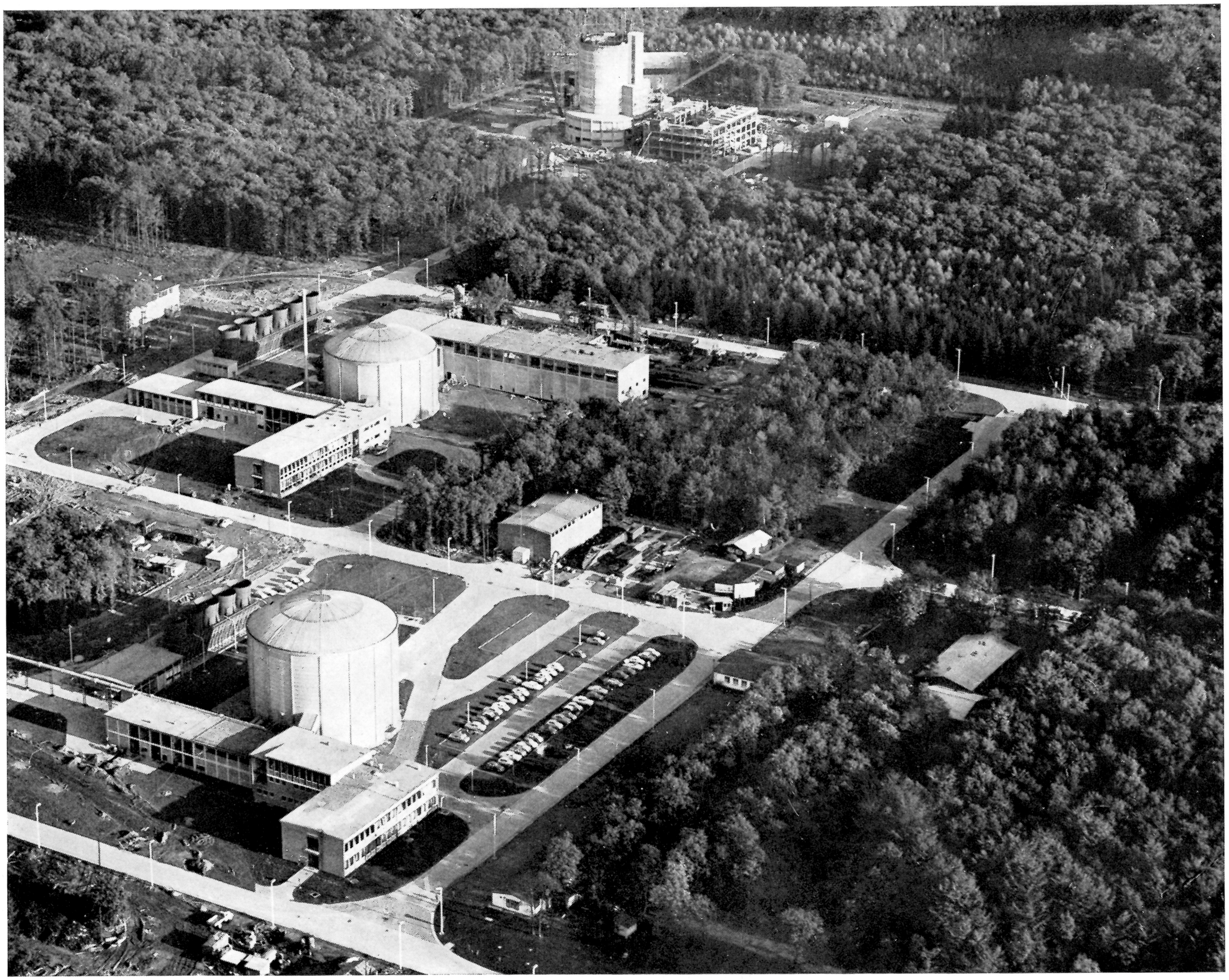




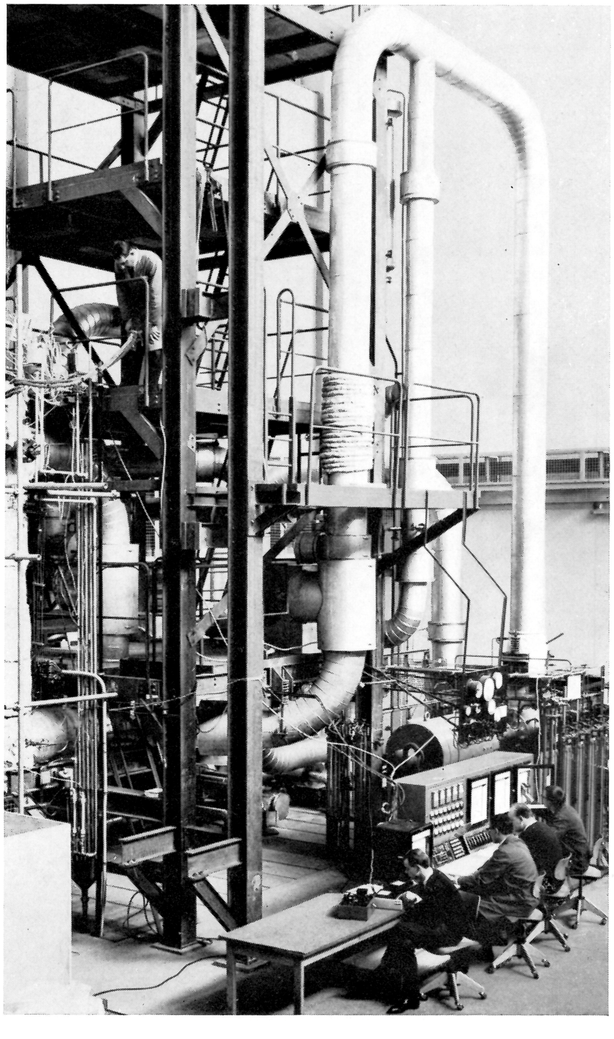


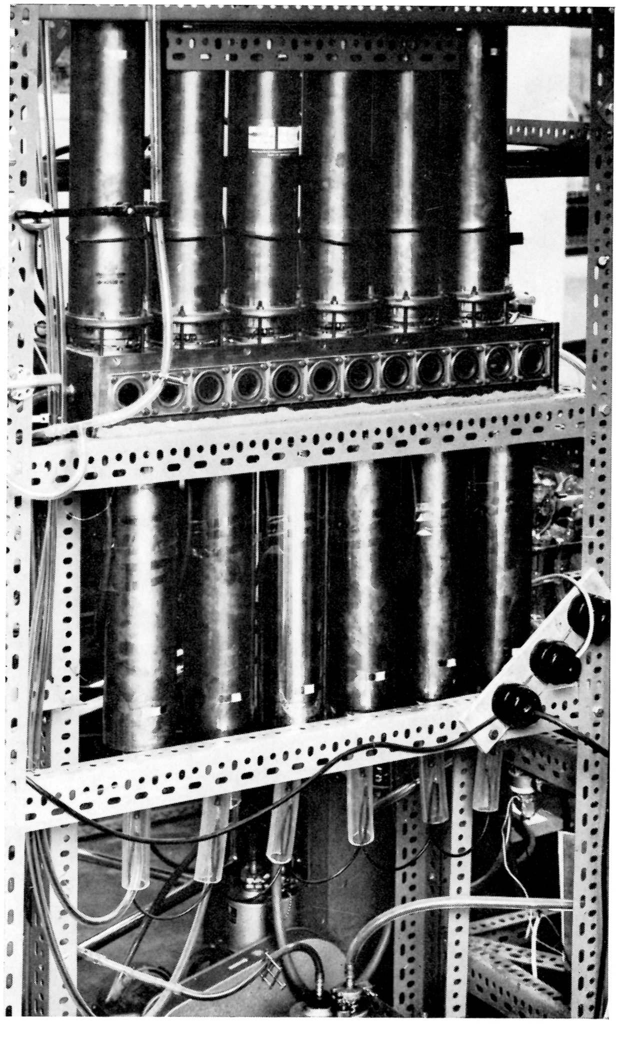
The principal tool of the Hahn-Meitner Institute of Berlin is a homogeneous solution reactor of 50 kW thermal output. The picture on the opposite page gives a view of the reactor from above. The picture below shows the whole institute with its now four sections: nuclear physics, nuclear chemistry, radiation chemistry, and mathematics.

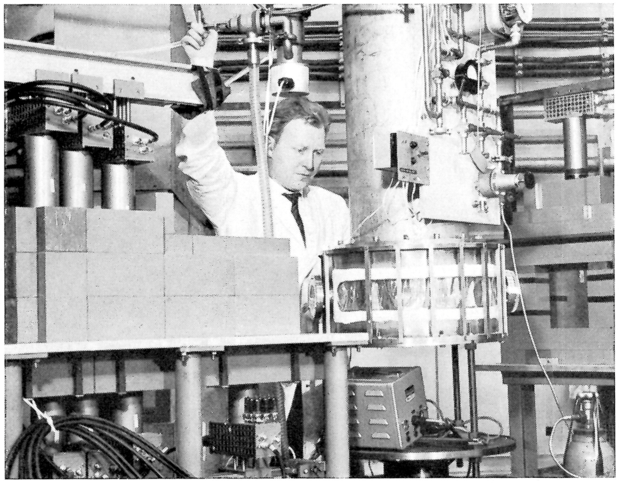


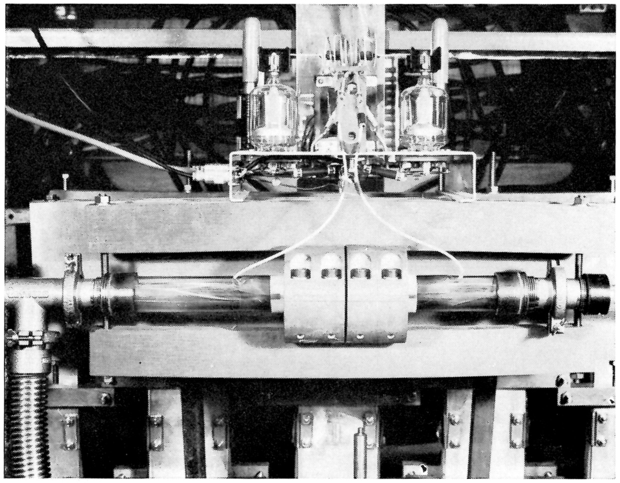


The second large nuclear research centre of Germany was established near Jülich, between Cologne and Aachen. The air view on the lower left shows the two research reactors **DIDO** and **MERLIN**, and behind them the **AVR** experimental power station in rough brickwork; this power station will be equipped with a pebble-bed reactor. The picture on the upper left shows an experimental gas loop for fuel element testing, the one on the upper right an experimental assembly for flash photolysis.



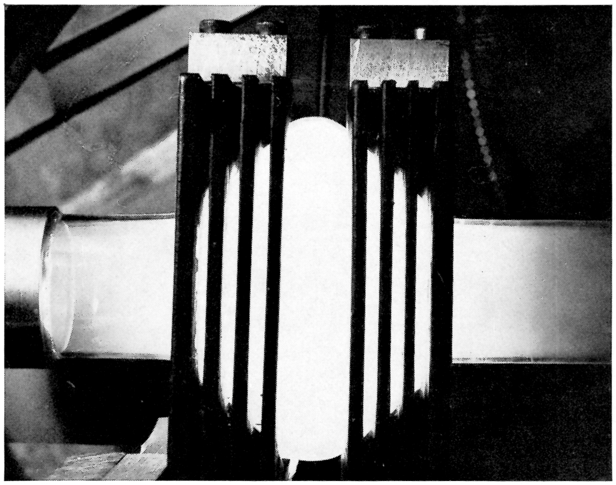


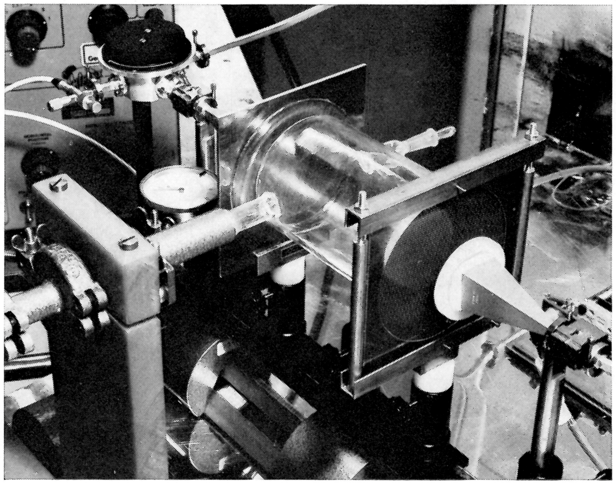


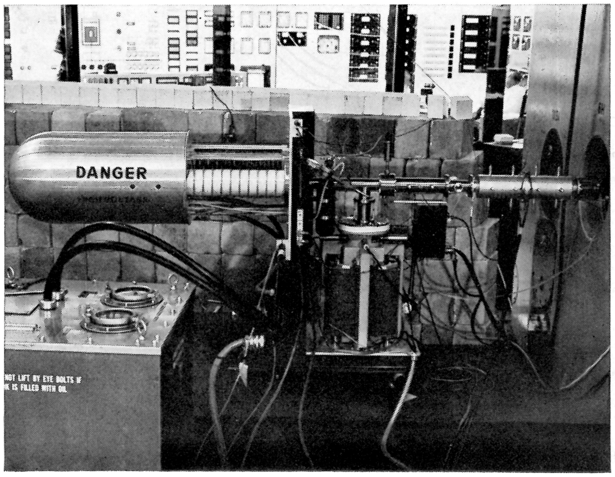


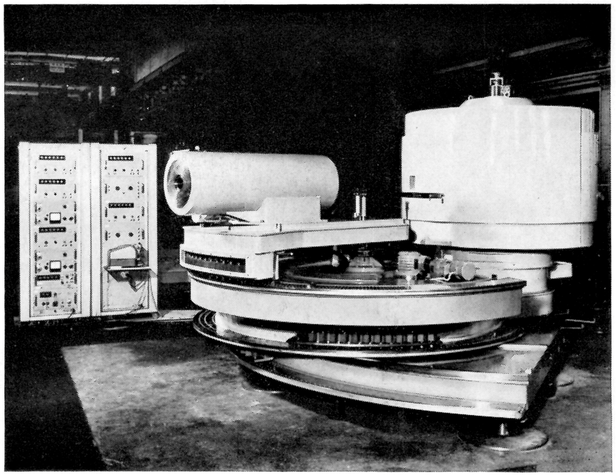
One of the main scientific efforts at the Jülich Nuclear Research Establishment is focussed on plasma physics. The picture on the opposite page is a view of the large experimentation hall of the Jülich Plasma Physics Institute; in the foreground: the fast magnetic compression experiment, in the background: a second 5 kJoule experiment with a vacuum UV-spectrograph. The picture on the upper right of this page shows details of an experiment for the production and fast magnetic compression of a plasma. The high frequency emitter to pre-ionize the gas can be seen above the discharge tube. On the upper left: an apparatus to study photofission of the deuterons in the energy range of 200 to 500 MeV.

Pictures in the upper row of this page also show activities of the Jülich Nuclear Research Establishment. On the left: the production of plasma in a cusp geometry prior to the main discharge of the compression battery, on the right: an interferometer for 8 mm microwaves to determine electron density in slightly ionized gas. The picture below on the left shows a pulsed neutron generator for reactivity measurements at the DIDO reactor, on the right: a three axis spectrometer.









by varying the temperature of the moderator. For reactor shutdown and control there are 17 absorbing rods altogether; however, one control rod will generally suffice. The heavy water discharged from the hot channels has a temperature of about 280° C. According to the moderator temperature required in each particular case, the heavy water will be cooled down to 70° C to 200° C. before it enters the moderator tank.

Each of the channels houses two fuel elements of almost 2 m. in length, these being interconnected by special couplings. Each element consists of a bunch of 37 zircaloy tubes which are filled with NO_2 pellets. The walls of the tubes are 0.6 mm. thick and the outer diameter of the tubes is 11.7 mm. At the upper end of each fuel element rod there is an outlet for fission gases. Apart from that each of the pellets has a plate-like cavity on one of its two front sides in order to compensate for the greater heat expansion on the central axis. The proposed UO_2 density is 10.6 $g./cm.^3$

Six of the 121 hot channels can be equipped for the testing of novel fuel elements and for the performance of boiling tests under normal operational conditions of the reactor. Two of these 6 experimental channels can also be used for experiments with other coolants at excessive pressures and higher temperatures. An advantage is that the multi-purpose reactor has a higher thermal neutron of flux density than other power reactors. It amounts to a maximum of about $2 \cdot 10^{14}$ $n/cm.^2$ sec. Correspondingly, the power produced in each of the experimental channels is considerable; each attains up to 4 MW. For its removal, additional steam generators are being installed in the reactor housing these being connected with the main steam circuit by means of a secondary circuit.

The estimated costs for the setting up of the multi-purpose reactor amount to DM 157 million; at least DM 20 million of this amount will be spent on development experiments mainly to make the channels accessible. The multi-purpose reactor was designed by Siemens-Schuckertwerke AG who are furnishing the plant or rather are responsible for the overall project in their capacity as project managers. The multi-purpose reactor is scheduled for completion by late 1965. The critical experiment has already been performed in a special hall of the Karlsruhe nuclear research centre, and the original fuel elements have been tested.

b) Fast breeder project

As far as reactor engineering is concerned the fast breeder project has by now become the main central effort of the Karlsruhe nuclear research centre. The breeder developed at Karlsruhe essentially differs from operating breeder reactors of the first generation–EBR I, EBR II, Enrico Fermi, and Dounreay–in so far as the nuclear fuel charge will not be plutonium metal but plutonium oxide. These ceramic fuel elements will guarantee the high burn-up required for the economic operation of a fast breeder. At Karlsruhe a burn-up of 50,000 to 100,000 MWd./t. is being considered.

This change ceramic fuel elements and thus to the second generation of fast breeders has far-reaching and fundamental consequences which are not obvious at first sight, and which include, in particular, the fact that the inherent stability of a fast breeder is no longer guaranteed by the immediately effective extension of the nuclear fuel. It is therefore necessary to make use of the Doppler coefficient with its mere nuclear effects. It is above all to of the Karlsruhe fast breeder group that they have grasped this interconnection. This group has thus logically followed the concept which was at the basis of the FR 2 design. A burn-up of 100,000 MWd./t. corresponds to a 100 per cent fission of all fissionable atoms initially present. Of course, this is only possible if the newly bred fissile material is available in the original fuel element and can therefore be converted. The modern heavy-water reactors also completely burn all the fissionable material which was initially in the reactor. Strictly speaking, reactors of this type cannot breed, although they can convert some amount of U-238 into plutonium that, if this plutonium is burnt in the same load, the initial U-235 core will theoretically have been utilized to 300 per cent.

Apart from comprehensive reactor calculations, safety studies and reactor conceptual designs, the Karlsruhe fast breeder project includes three large experimental plants for the performance of defined experiments, which are called STARK, SUAK, and SNEAK. In addition, the Karlsruhe nuclear research centre contributes to the American SEFOR-project.

The abbreviation STARK stands for Schnell-Thermischer-ARGONAUT-Reactor Karlsruhe (fast-thermal Argonaut reactor). As is well known, the normal Argonaut reactor is equipped with a central cylindrical graphite reflector. At Karlsruhe this reflector is replaced by a fast core, resulting in a coupled reactor. Both the new fast core in the centre as well as the annular thermal core outside are subcritical, and will go critical only if they are put together. The dynamics of such a coupled reactor almost entirely depend on the thermal outer core, so that its operational behaviour remains simple and clear. Nonetheless, it is possible to work with fast neutrons in the centre, and to some degree study, the dynamic behaviour of a fast core. Constructional modifications on the Karlsruhe Argonaut reactor were completed by spring 1964 so that a fast core will go into operation for the first time in Europe in the summer of 1964.

SUAK is the abbreviation for Schnelle Unterkritische Anordnung Karlsruhe (fast sub-critical assembly). It is a pulsed experiment with fast neutrons which profits from the wide experience the Karlsruhe Institute for Neutron Physics and Reactor Technology has gained in pulsing thermal assemblies; this, by the way, is a technique which was based on the German reactor development during the war. With regard to neutron backscattering, SUAK is accomodaetd in a housing of corrugated sheet steel, surrounded at some meters distance by a high annular mound of earth serving as a neutron shield. In the middle of the little house a cube of about 30 cm. square is set up from small pellets of enriched uranium. The enrichment is kept so low that the cube does not become critical, but has a multiplication factor of only 0.8 to 0.9. By means of a pulsed neutron source fast neutrons are shot into this fuel cube for a short while, the subsequent decay of the neutron field being observed. On the basis of these observations it is then possible to say something about the scattering and absorption parameters of the fuel combination. In addition, the low-energy section of the neutron spectrum can be measured by means of a time-of-flight spectrometer.

The abbreviation SNEAK stands for Schnelle Nullenergie-Anordnung Karlsruhe (fast zero power assembly) and it is this experiment which is the most impressive. While, for safety considerations, SUAK and STARK only use U-235 as fission material, SNEAK can also utilise a plutonium core. Correspondingly, a multi-layer containment is needed, so that SNEAK requires large and high buildings and the total effort is similar to that in the case of a large-scale reactor. SNEAK is a large and very flexible fast reactor which is expected to achieve a maximum output of several hundred watts. Owing to its "box of bricks" structure, fast reactor assemblies of different size, form and arrangement are possible and their neutron physics can be studied. As in the case of SNAK and STARK the single parts of the SNEAK fuel element are small square pellets having a cross-section of 51 by 51 mm. and a thickness of 3 and 6 mm. respectively. Such pellets are fabricated of all materials occuring in fast reactors such as uranium, plutonium, steel, sodium, graphite and nickel, some of theme in a suitable chemical form and in steel canning. By means of automatic charging devices different layers of pellets can be inserted into square steel tubes and these square fuel elements are assembled to form the core which is going to be examined. Thus it is possible to study a wide range of combinations of materials. Up to now no critical zero power assembly of this flexibility exists in the world which would be suit-able for a wide use of plutonium with higher isotopes. In particular, SNEAK permits to study the power coefficient which decisively influences the stability characteristics of the future power reactor. In addition, SNEAK has a special heating device so that the Doppler coefficient–so important to the inherent stability–may be investigated.

Originally, the logical completion of this series of experiments was to be a fast dynamic test reactor, the Karlsruhe Powder Godiva. It was meant to be used for performing power excursions to study the Doppler coefficient; an oxide compound in powder form was to be inserted as nuclear fuel. While it was still discussed at Karlsruhe in the autumn of 1961 how to keep the cost of building this test reactor within tolerable limits, physicists of U.S. General Electric reported on the EFOR project at an IAEA conference held in Vienna. This project was almost exactly what one was looking for at Karlsruhe. Thereupon American and German scientists discussed this matter as good colleagues and the idea cropped up to realize the EFOR project with German participation. Later on these first contacts developed into official intergovernmental negotiations. One major difficulty resulted from the fact that the American Atomic Energy Act expressly states that no reactor in the U.S.A. must be controlled by non-Americans. In this connection the term "control" has to be interpreted to include even a financial participation of 5 per cent. At last, however, a concept was found under which the German group could share experience and research results obtained from a $ 25 million programme while making a financial contribution of $ 5 million. The following agreements were negotiated and concluded:

Gesellschaft für Kernforschung at Karlsruhe and the group Southwest Atomic Energy Associations, called SAEA, concludes a contract which provides that both groups shall jointly finance the construction of a dynamic test reactor–now called SEFOR–the abbreviation of Southwest Experimental Fast Oxide Reactor–at Fayetteville in the North American State of Arkansas. At the same time SAEA, also acting on behalf of Karlsruhe, concludes a contract with General Electric of San José for the construction of this reactor. The total costs of this reactor are estimated at $ 12.4 million of which Karlsruhe pays 5 million, SAEA 5.9 million and the supplier 1.5 million. Being the supplier, General Electric will defray any additional costs in excess of the estimated $ 12.4 million for the erection of the reactor. Furthermore, SAEA will conclude–again on behalf of Gesellschaft für Kernforschung in Karlsruhe–a contract with the U.S. Atomic Energy Commission for the research and development programme which is estimated to cost $ 12.5 million, and which will be realized by means of this dynamic test reactor. General Electric is in charge of this programme under another programme which has to be approved by both Karlsruhe and the U.S. AEC, and which will be paid by the AEC. The nuclear research centre of Karlsruhe has the right to send members of its staff to San José or Fayetteville to participate in the design, development, construction, and experimental activities. For the future management and control of this project two committees were set up, the so-called project review committee which keeps an eye on the main trends of the overall project, and the technical policy committee which is in charge of the scientific and technical activities. Scientists of the Karlsruhe centre are sitting on both committees. From the technical angle SEFOR is a sodium-cooled fast neutron reactor, the core of which contains 240 g. of plutonium. Its thermal output reaches 20 MW. This output, however, is not used to produce electrical power.

For the period ending late in 1967, DM 185 million are earmarked for the fast breeder project, DM 25 million of this amount going to SNEAK. The European Atomic Energy Community participates in the project under an association contract under which Euratom bears 40 per cent of the total cost. The preliminary aim to be reached by 1967 is to find the parameters for a larger prototype test reactor. At Karlsruhe this development is deemed urgent, since from about 1970 larger amounts of the so-called dirty plutonium will result from the future thermal nuclear power stations in operation so that the development of the fast powerbreeder becomes an economic necessity. Dirty plutonium is–as opposed to the plutonium used in the bomb–a composition of isotopes resulting if the nuclear fuel remains in the reactor for a long time and containing also a large percentage of the heavier isotopes.

c) Main point of activity: hot chemistry

Activities at the Karlsruhe nuclear research centre are by no means limited to reactor development and the associated neutron physics. A second main field of activities is chemistry, in particular, hot chemistry. A country which is attempting to establish a reactor industry of its own will sooner or later have to turn to the reprocessing of spent fuel elements. This becomes all the more urgent if reactors are operated with highly enriched fuels and plutonium. In this case, the fuel inventory accounts for a considerable part of the investment costs, and it is expedient to have the shortest possible fuel cycle. Moreover, Germany is a country with a highly developed chemical industry which will make increasing use of radiochemical processes, let alone the applications of radioactive isotopes for chemical analyses and process studies.

In order to create the prerequisites for the construction of a plant for the chemical reprocessing of irradiated nuclear fuel, a group of German firms was assigned the task to draft a conceptual design. The plant is scheduled to have a capacity of 40 t. of natural uranium or low-enriched uranium per year. The technique used will be liquid-liquid extraction. The nuclear research centre of Karlsruhe was proposed for a site; however, Gesellschaft für Kernforschung will hardly operate the plant. Operation should be the responsibility of a qualified firm–or a group of firms–not on a private enterprise basis following the American pattern at the expense of the Bund.

Apart from this type of reprocessing which may almost be termed conventional, the Karlsruhe chemical institutes concentrate to an ever increasing extent on novel or improved techniques for the reprocessing of fuel elements from fast breeder reactors. The institute for radiochemistry of the Karlsruhe nuclear research centre developed for example a separation stirrer for rapid liquid-liquid extraction the inner part of which acts as a centrifuge. With this device non-continuous extraction can be carried out on a laboratory scale in about 10 to 20 seconds, but the apparatus may also be used for continuous extraction.

If it has not yet become quite evident that in Karlsruhe the emphasis is on chemistry, this is mainly due to the fact that it takes relatively long to build radiochemical laboratories, in particular hot cells. The same applies to the Euratom Institute for Transuranic Elements which is not part of the Karlsruhe centre organizationally, but which is being built on its site. Its construction took much longer than was planned originally. According to J. Blin, director of the Institute, the main advantage the Institute offers is that the means for fabrication, research and examination of plutonium fuel elements are concentrated in one place.

Even though the European Transuranic Institute is part of the Joint Euratom Research Centre and thus works on a scientific programme which does not necessarily coincide with the Karlsruhe interests the partners will profit from one another's work as soon as the Institute will fully have taken up its activities.

d) Isotope separation and radiation biology

The institute for nuclear chemical engineering under Professor Erwin Becker, which is part of the Karlsruhe centre, is, no doubt, a research establishment of internal renown. The so-called separation nozzle process developed in this institute has met with particular interest. Segregation in space of various heavy components in an expanding supersonic beam is the basis of this process. A much better economy of this method was recently achieved by using light additive gases, and by mechanical diversion of the beam in the space between the nozzle and the separator which separates one part of the beam. Thus when using a mixture of 5 mols of uranium hexafluoride and 95 mols of helium and a beam diversion by 180° the efficiency of uranium isotope separation was three times greater than that of the usual diffusion process. Since the additional compression of the helium gas requires considerable expenditure, this isotope separation technique though being more effective cannot, at the present state of the art, compete with the diffusion technique from the cost angle. However, there is reason to believe that the new technique will soon become economically more efficient than the old one. Another field of work at the institute is the enrichment of heavy water. In a joint effort between the firms of Degussa at Frankfurt and Uhde at Dortmund a new process was developed to enrich heavy water. This process is based on the high pressure exchange between hydrogen and a catalyser suspension. Experiments carried out on a semi-technical scale make the process appear economically attractive.

In addition to hot chemistry special emphasis is placed on radiation biology. At Karlsruhe scientific work in this field aims at obtaining new insights into the complex physical and chemical processes which are the basis of the harmful effects of radiation on living organisms by systematically investigating rather simple biological objects, such as bacteriophages. For these investigations one does not only use ordinary X-rays, but also neutron radiation which plays such an important part in reactor engineering. A special laboratory for neutron biology was set up to this end. The most modern means such as microwave spectrographs are employed to detect the early stages of radiation effects on biological organisms, and above all the fuel radicals resulting from irradiation. On the other hand work is under way at the Karlsruhe Institute to develop medicaments that may be used in case radioactive substances have got into the organism. Such medicaments are meant to remove rapidly and completely any radioactive substances which are infused into the human body due to an occupational accident. More than basic research has been done in this field and the institute has won a leading position in the world.

In order to be able to carry out such research and development work the Karlsruhe centre does not only use the neutron radiation of an efficient reactor but also of one of the most modern medium-size particle accelerators in Europe, a so-called isochron-cyclotron or Thomas-cyclotron. It differs from the usual cyclotron as to the formation of its magnetic field. The Thomas-cyclotron may be operated at constant acceleration frequency and thus a high beam intensity is achieved. The energy of the particles amounts to 50 MeV. in the case of deuterons and 25 MeV. in the case of protons. The amperage of the inner beam attains 100 μA. and that of the exit beam more than 10 μA.

Furthermore, experimental nuclear physics with nuclear spectroscopy and high-energy physics have also found their place at Karlsruhe. Mention should also be made of the Institute for Reactor Components which is particularly concerned with the development of a superheat reactor, last but not least with a view to developing the cooling system for the large nuclear breeder power station which is to be built later on. One does not think so much of a boiling water reactor with integrated superheating but rather of a steam cooling system as used in gas-cooled reactors, i. e., under high pressure and high flow speeds. Finally, the nuclear research centre of Karlsruhe includes training facilities such as a School for Nuclear Technology and an Institute for Radiation Protection.

2. THE JÜLICH NUCLEAR RESEARCH ESTABLISHMENT

Apart from the technical development, pure and applied research comes even more to the fore in the Jülich nuclear research establishment than it does in the Karlsruhe centre. This is partly due to the fact that this second largest German establishment was originally planned to comprise some special university institutes of the Land Northrhine-Westphalia, whereas the original main task of Karlsruhe was to develop a German reactor. Moreover, the construction of the Jülich establishment was initiated at a later date than that of Karlsruhe, so that from the very beginning Jülich seemed to be somewhat overshadowed. In the meantime, however, this difficulty seems to have been overcome and as far as the dimensions are concerned the lead of Karlsruhe is no longer so great. At present, some 2,200 people are employed at the Jülich nuclear research establishment and the current financial expenditures are in the order of magnitude of DM 50 million per annum and that on investments amount to DM 50 million. These funds are more or less exclusively raised by the land of Northrhine-Westphalia, the Bund contributing only a few millions to the investments.

Undoubtedly, the Federal Atomics Ministry at first considered the Jülich nuclear research establishment a rival of "its own" Karlsruhe nuclear research centre and was afraid of a certain splitting up not only of the financial means but also of the available expert personnel. But since the Karlsruhe nuclear research centre–when taking into account the plans for its further expansion that are still under discussion–will reach an order of magnitude which many a critical observer considers the optimum for a national nuclear research centre–whether or not such an optimum actually exists and whether it should be aimed at by deliberately restricting its growth is, in principle, a vexed question–the Federal Republic of Germany has room, more than ever, for a second large nuclear research and development centre. There continues to be worthwhile and fascinating problems which Jülich tackles with enthusiasm and skill now that the first phase of building has been completed.

a) Thorium breeders

This reactor type includes the development of reactors exploiting the thorium-uranium breeding cycle. In the long run, they appear as interesting as the plutonium breeders since the world reserves of thorium are at least of the same order of magnitude as those of uranium. This development need not necessarily lead up to a true breeder reactor. For the foresecable future, it is much more important to produce energy as cheap as possible by obtaining high burn-ups which, according to similar considerations on the fast breeder, seem to be possible even at high conversion rates.

But contrary to the plutonium breeder it is not necessary to remain within a definite neutron energy region. The thorium-uranium breeding cycle operates in the thermal as well as in the epithermal and even in the fast region, so that the development of such a breeder type can naturally be much more flexible than that of the uranium-plutonium breeding cycle.

Accordingly the main task which the Jülich nuclear research establishment has set itself for the coming years is the development of thorium reactors and the practical development of the associated breeding cycle. After lengthy negotiations a contract of association was concluded in May 1964 between the European Atomic Energy Community, the Jülich nuclear research establishment, and Brown Boveri/Krupp Reaktorbau GmbH for the purpose of continuing one development of the pebble-bed reactor into a high-temperature reactor having a thorium-uranium breeding cycle and being designed for large power plants. This contract runs from 1963 to 1967. The total expenditures to be incurred under this contract are fixed at DM 80 million, 50 per cent of which will be raised by Euratom. Under present circumstances this percentage is rather high. This is due to the fact that the association contract aims more or less at the preparation of initial designs for a prototype reactor with a thermal output of 500 MW., which would later have to be built without the participation of the European Atomic Energy Community. The relatively high contribution of Euratom is, so to speak, a prepayment towards the construction project resulting from the contract. It is called THTR-project which is the abbreviation for Thorium-High-Temperature-Reactor. Though the Bund does not officially appear in this association contract it heavily contributes to this project through the Jülich nuclear research establishment.

The rather high thermal output of the THTR-prototype amounting to 500 MW., which would approximate to an electrical output of 200 MW., is required because of the envisaged high steam temperatures which require a large enough core and a relatively low neutron leakage through the core walls. The diameter of the pebble-bed of the AVR-pebble-bed reactor construction of which started in 1960 in the immediate neighbourhood of the Jülich nuclear research establishment amounts to only 3 metres horizontally, which will not be quite sufficient for obtaining an acceptable conversion rate. For obvious reasons this AVR-reactor will perform the functions of an experimental and testing equipment within the THTR-development-project. During the research and development work performed under the THTR-project priority is given to the development of fuel elements, which had been difficult to do even in the case of the AVR-project.

An American 20-million-dollar development showed us how it is possible to give a gas-tight cladding to the uranium carbide particles with which the graphite fuel element balls are filled. These so-called "coated particles" largely retain the gaseous fission products which are formed in the interior of the uranium carbide particle, so that the contamination of the inert gas mixture cooling the primary circuit can be kept within reasonable limits. Therefore, it seems possible today to make full use of the high temperature load capacity of graphite as a fuel element carrier and to achieve a good neutron economy with high burnups. Furthermore, the THTR-development project is concerned with the investigation of the resistance of graphite to irradiation and corrosion, the mass transport problems within the primary circuit, the burnup measurements on individual fuel element balls and with the neutron physics of graphite-thorium-uranium systems.

Beyond the scope of this THTR-contract of association the Institute for Reactor Development of the Jülich nuclear research establishment has embarked upon a comparison of different thorium reactor concepts with a view to reaching an optimal conversion ratio as well as on a comparison study of the economics of such reactors. In this context a new reactor concept is being discussed, the so-called MOSEL-reactor, which has been developed at the Institute for Reactor Development. MOSEL stands for "Molten Salt Epithermal Reactor". This concept is based upon the molten salt technology, developed over the last ten years in the U.S.A., and attempts to include the reprocessing of the nuclear fuel in the operational procedures of the reactor, which may therefore be termed a reactor with integrated reprocessing.

The nuclear fuels used here are uranium and thorium fluorides dissolved in molten fluorine salts. The reactor operates in the epithermal neutron region on the two-zone/two-liquid principle, which means that the core is separated from the blanket. The salt alloy contained in the core is kept in a molten state to the extent necessary for the fuel to mix, for fission products to be removed and for fresh fertile fuel material to be added. The core is cooled by the blanket alloy. The reactor operates at a pressure of 10 to 15 atmospheres and at a coolant outlet temperature of approximately 650° C. Thus the reprocessing of the fuel is as follows: on the one hand, the uranium–newly formed from thorium–fluorides and, on the other, the carrier–salt alloy loaded with fission products is discharged.

Within the thorium reactor development Jülich is moreover concerned with the development and the construction of critical and subcritical assemblies, in which the moderation ratio as well as the charge of fertile material and fuel and the temperature may be modified within a wide range.

b) Plasmaphysics

In addition to these activities in the reactor engineering field there is another main field of effort at Jülich, namely plasmaphysics. In this connection, there are primarily two experimental approaches:

1. fast magnetic compression and
2. the development of a plasma accelerator.

The fast magnetic compression experiments, which were at first realized in a relatively small assembly, are now well advanced. The values of the plasma attained correspond to those of other laboratories–such as those of Washington and Los Alamos. In the plasma accelerator the plasma is formed by means of a conic coil and by fast magnetic compression and undergoes an additional axial acceleration because of the geometrical form.

Under an association agreement with Euratom, the Institute for Plasmaphysics of the Jülich nuclear research establishment has recently built a pulsed high-current device which uses a condensation battery of 600 kW. Joule energy content. This experiment went into operation only a short while ago and it is hoped to have thus achieved temperatures, particle densities and confinement periods in an order of magnitude that has to be considered satisfactory with a view to nuclear fusion experiments of a positive energy balance.

The two reactors of the Jülich nuclear research establishment–MERLIN and DIDO–did not operate at full power until August and September 1963 respectively and they were officially handed over to the nuclear research establishment in late October 1963. It stands to reason that the development possibilities of a nuclear research centre are very limited as long as it does not utilise a nuclear reactor. Moreover, the example of the Jülich nuclear research establishment did not confirm the fact that nuclear licensing proceedings which, in the Federal Republic of Germany, are the responsibility of the Land authorities, are less complicated and settled more rapidly for the simple reason that the project to be licensed is an institution of the respective Land. Now there is every reason to believe that no further important obstacles will impede the full development of the Jülich nuclear research establishment, the more so, simce the original idea of the double functions with regard to the universities of the Land was abandoned and Jülich is tackling problems that clearly go beyond the activities of any university or technical high school. The scientific and technical Member of the Board of Directors of the Jülich nuclear research centre, Alfred Boettcher, made the following statement: "We perform the work that cannot be done by university institutes–though, however, in close operation with them–if it were only for the reason to attract the scientific and technical young blood we need."

3. THE GEESTHACHT REACTOR STATION

The third supra-regional nuclear research and development centre of the Federal Republic of Germany is the reactor station at Geesthacht-Tesperhude near Hamburg operated by the Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt. Apart from the four German coastal Laender Bremen, Hamburg, Lower Saxony and Schleswig-Holstein the sponsoring bodies of the afore-mentioned Company include the Bund and some thirty industrial firms including shipbuilding and shipping companies, the iron and steel industry, banks and insurance companies. At present, the total number of employees of the Company amounts to some 300.

What the fast breeder project is to Karlsruhe and the thorium reactors to Jülich, the German nuclear ship is to Geesthacht. Construction of the hull was ordered in November 1962. In September 1963 laying down took place at the Howaldtswerke of Kiel and in June of this year the ship was launched. This ship is an ore freighter with a water displacement of 26,000 t. and a load capacity of 15,000 t. Its total length amounts to 72 m., its width being 23.4 m. A consortium of industrial firms, namely Deutsche Babcock & Wilcox Dampfkesselwerke AG and Interatom, i. e., Internationale Atomreaktorbau GmbH, was awarded the contract for the construction of an advanced pressurized water reactor (FDR) which is to propel the ship. This reactor having an outpout of 10,000 to 11,000 shaft horsepower will give the ship a speed of 16 knots. The construction order for the reactor was placed in November 1963 and delivery of the completed ship is scheduled for the end of 1966. The European Atomic Energy Community will probably participate in this project by way of an association contract. It promoted the preceding activities in connection with nuclear ships research and development by research contracts.

The FDR-reactor has a thermal output of 38 MW. The coolant is light water which is circulated at on operational pressure of 64 atmospheres. A fuel charge of 2.95 t. of uranium dioxide with a U-235 enrichment of 3.6 per cent enables a non-stop three-year operation of the ship as a cargo vessel. The FDR is the first reactor of the pressurized water type to house the steam generator and the primary circulating pumps in one pressure vessel. After its completion the German nuclear ship will be used for research purposes, so that it may be used at a later date to test even more advanced designs of the pressurized water reactor such as the possibility of permitting local boiling on the fuel elements. Moreover, it is planned to test other reactor types in this ship later on, some of which were already discussed in November 1963 when the construction of the first reactor was decided upon. The reactors to be tested include an organic-moderated reactor (OMR), a pressurized water reactor of the ordinary type and perhaps an air-cooled reactor using light water as a moderator. Thus, the Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt pursues a far-sighted nuclear ship development. Besides the immediate aim to build and equip the ore freighter-basic design activities and studies are carried out under a longterm programme. This programme includes, e. g., activities with regard to the optimization of reactor shields which are naturally of special importance in non-stationary reactors. The optimization of collision barriers of nuclear ships is effected by model experiments. Finally, control rods and fuel elements are tested on a rolling stand under the special mechanical conditions of the ship movements.

The swimming pool reactor of the Geesthacht reactor station, which has been operating since October 1958, has an interesting peculiarity: it has two cores. Its swimming pool was rather long originally so as to be able to get the reactor core into different irradiation positions. Now, a second core suspended from a bridge has been inserted into the existing swimming pool. This core is equipped with a separate control panel and can be advanced parallel to the first core. For the time being, however, the maximum cooling output of the Geesthacht reactor plant amounts to 5.2 MW. only, so that both reactors cannot increase their output simultaneously. But it is proposed to increase the total output of the cooling system from 10 to 15 MW. in the foreseeable future, in order to permit simultaneous operation of both cores at full power or even greater.

A speciality of the swimming pool of the Geesthacht reactor plant is the so-called irradiation window–actually a device mounted in front of the pool and directly facing the core, a device covered by an aluminium plate and reaching into the reactor pool from outside a test car may be taken to the window through a tunnel. This so-called "irradiation car" is equipped with a large table on which the experimental assemblies, such as certain shield assemblies, are first mounted outside the radiation zone. A remote handling device then propels the car move up to the window where it is irradiated through the aluminium plate. Thereupon the car returns to a hot cell–again by remote handling–in which the assembly to be tested can be thoroughly examined.

Furthermore, the Geesthacht reactor station utilises a rolling stand on which reactor components weighing up to 2.2 t. are tested under simulated load conditions at sea with regard to their mechanical functioning in the event of accelerations of up to 3 g. This is a machine which is very similar to a crank press with the exception that the press die does not pound on to the bottom but that it only slides up and down comparatively high speed. Numerous tensile strip charts record the mechanical load of the test specimens under the influence of positive and negative acceleration.

Finally, the Geesthacht reactor station has at its disposal a recently set up experimental hall where critical experiments can be assembled. It is a concrete rotunda with an inside diameter of 22 m and an inside altitude of 12.5 m. In the centre there is a large mounting area, a type of table, on which any critical configuration can be assembled.

4. UNIVERSITY REACTOR PLANTS

When, in a description of this kind, one leaves the narrow circle of the three Federal German nuclear research centres having more or less defined technical targets and turns to the wider field of institutes and research stations that are entirely predominantly engaged in basic research, one will soon be confronted with a fundamental difficulty: How is it possible to judge something for which there are no measures? Productivity in the field of basic research is reflected by publications, but it would surely be a fallacy to judge the quality of an institute by the number of publications it issues. It goes without saying that the amount of apparatus in a research institute is by no means a guarantee of the scientific value of its work. Therefore, the following survey has to restrict itself more or less to the equipment of the most important research institutions, and it cannot claim to be complete.

The university research reactor of which the best use has been made to date is that of the Laboratory for Technical Physics of Munich Technical University at Garching, headed by Professor Heinz Maier-Leibnitz. At present, there are 25 scientific experiments performed in this reactor, and some 40 other experiments outside the reactor hall are connected with the reactor's utilization, mostly with regard to the irradiation of samples of material. As is well-known the Nobel laureate, Rudolf Mössbauer, came from this institute where he performed a substantial part of his work in connection with the discovery and development of the effect named after him.

Important focal points of the activities performed at the research reactor of Munich Technical University are solid state physics, nuclear physics and radiochemistry. Experts are greatly interested in the institute's low-temperature (cryogenic) irradiation plant, which achieved radiation doses and Frenkel defect concentrations that by far exceed those so far attained abroad. This is partly due to the high refrigerating capacity of the plant at Garching and to some extent to the high flux of fast neutrons which is produced by the 1 MW. swimming pool reactor of Garching. Its 27 fuel elements are of the MTR-type (Material Test Reactor) and the original U-235 enrichment of 20 per cent was raised to 90 per cent. Moreover, the core received 24 elements filled with graphite and mounted at the outside as an additional reflector to the light water of the pool.

In the immediate neighbourhood of the Garching reactor a new building of the Institute for Radiochemistry of Munich Technical University, headed by Professor Hans Joachim Born, is nearing completion, so that it will be possible to use the reactor to an even higher degree for chemical research experiments. At the same time the institute pursues applied and pure radiochemistry–and above all the so-called recoil chemistry. Finally, it has to be mentioned that due to Mössbauer's return to Germany, i. e., to Munich Technical University, a generous expansion of the institute's division of physics has been envisaged. These new buildings of the institute are again set up in the immediate neighbourhood of the Garching reactor station which will thus develop into a centre of physical research at Munich Technical University. Such an expansion entails considerable organizational changes, which are of extreme importance for basic research performed at the universities and technical high schools in Germany.

The centre of the Hahn-Meitner-Institut of Berlin is the homogeneous reactor with a thermal output of 50 kW. This reactor was selected primarily because it lends itself perfectly for radiochemical work. The gaseous fission products formed during the operation are trapped and represent a source of strong gamma radiation, the total activity of which reaches 320,000 curies in case of continuous full load operation. The dose rate of the scaled gases amounts to 10^5 r/h. at a distance of 20 cm. In consideration of the great importance of radiation chemistry this division was recently separated from the institute's nuclear chemistry department so that the Hahn-Meitner-Institut now has four departments: nuclear physics, nuclear chemistry, radiation chemistry and mathematics. The nuclear physics department will install a 5.5 MEV. Van-de-Graaff-accelerator in summer 1964.

Since the beginning of 1958 the Institute for Nuclear Physics of Johann-Wolfgang-Goethe-Universität at Frankfurt on the Main has had at its disposal a homogeneous reactor with a thermal output of 50 kW. Moreover, the institute has two particle accelerators, namely a 1.3-MeV.-cascade generator and a 6-MeV.-Van-de-Graaff-belt-type generator. The research programme of Frankfurt University mainly extends to nuclear physics in the low-energy region, such as studies on the structure of the atomic nucleus and to the field of neutron physics. Furthermore, the tradition of the old Regener-Institut is being continued at Stuttgart and Weißenau with activities on cosmic radiation.

The reactors at Munich, Berlin, and Frankfurt can be considered the tool of the first post-war nuclear research activities in the Federal Republic. Another new project is the TRIGA-reactor which is being built for the Institute for Inorganic Chemistry and Nuclear Chemistry of Mainz University. As is well-known, reactors of this type are marked by a high degree of inherent safety so that they can safely be used for pulsed operation, during which the thermal output of 0.1 MW. may, for a split second, be increased to 250 MW. Accordingly, the neutron flux increases by 2 to 3 decimal powers.

Finally, mention has to be made of the research reactor (Meßreaktor) of the Physikalisch-Technische Bundesanstalt of Brunswick which is still under construction. It is a swimming pool reactor which, however, differs from the normal type in that its core can be divided into two. A 75 cm.-wide container being filled with heavy water is placed between the two cores, and a homogeneous field of thermal neutrons will develop. This field of neutrons is mainly used for calibration purposes. Apart from this the Bundesanstalt of Brunswick is to carry out neutron physics research.

The Siemens training reactors are very popular. During the governmental exhibition which is organized under the auspices of the third International Conference on the Peaceful Uses of Atomic Energy at Geneva one of these reactors is displayed by the Federal Republic of Germany. Two further reactors are in operation at the Institute for General and Nuclear Technology of Berlin Technical University and at the Institute for Reactor Technology of Darmstadt Technical University. The Institute for High-temperature Research of Stuttgart Technical University will get the unit which is on display at Geneva and further reactors of this type are ordered for the engineering school of Hamburg, the engineering school of Ulm, and Aachen Technical University. Moreover, such a training reactor is already operated at the Garching reactor centre owned by Siemens-Schuckertwerke AG. The great interest displayed in this reactor can best be explained by its very simple control. Its core is a suspension of U_3O_8 powder with polyethylene as a moderator. The whole core is shielded by an absolutely gastight aluminium container, so that no air-exhaust problems result. The thermal output of the reactor amounts to 0.1 W. so that it requires no cooling system. Therefore, it is possible to set up this reactor in any existing engineering laboratory hall without any further constructional measures. Its maximum thermal neutron flux amounts to $5 \cdot 10^6$ n/cm.^{2} sec.

5. THE GERMAN ELECTRON-SYNCHROTRON

The list of German nuclear research establishments would not be complete without mentioning DESY, the German electron-synchrotron of Hamburg, which began to operate early in 1964. Due to its capacity to accelerate electrons to 6 GeV., DESY can be compared with the similar plant of the Massachusetts Institute of Technology at Cambridge/U.S.A. and with that at Erevan/U.S.S.R. Britain owns a 4-GeV. electron synchrotron–a joint venture of the universities of Glasgow, Liverpool, and Manchester. Due to the fact that it is envisaged to bring the Hamburg cyclic accelerator's output up to 7.5 GeV.–which will be done in the foreseeable future–probably in 1965–this electron accelerator will even be the largest in the world for some years to come.

At DESY, electrons are accelerated in a closed circulation of 100 m. diameter which is occupied by 48 electromagnets. 16 cavity resonators are used as accelerating gaps. The electrons are pre-accelerated to 40 MeV. in a linear accelerator and reach their final energy of 6 GeV. after approximately 10,000 circulations within 10 milliseconds. During this process the magnetic field increases to 6.3 Kilogauss. The electrons are coupled to the magnetic field according to the well-known principle of strong focusing which is also applied to modern proton cyclic accelerators.

The German electron synchrotron was put into operation without any major difficulties. The full output of 6 GeV. was reached giving a radiation intensity of the accelerated electron beam of $3 \cdot 10^{10}$ electrons per impulse. This energy is sufficient to discover details of the protons and neutrons structure that are 30 times smaller than their diameter. The use of the accelerator will, however, not be limited to such studies, it will also be used to produce and investigate a large number of instable elementary particles. In the preparation of these experiments a hydrogen bubble chamber with a diameter of 80 cm. was built in co-operation with engineers and scientists of the French nuclear research centre at Saclay, in order to be able to study photoproduction processes. The investigation of the photoproduction of individual mesons requires the construction of a large magnetic spectrometer consisting of four lenses and two deflection magnets.

The investments for the construction of DESY amount to DM 85 million. An additional DM 25 million are necessary so as to provide the constructional and technical prerequisites for the experimental activities envisaged. These total investments funds of DM 110 million are raised as follows: DM 83 million by the Bund, DM 17 million by the Land Hamburg, and DM 10 million out of the Volkswagenwerk Foundation. DESY already employs more than 350 people, a number which is expected to rise considerably until full operation is reached. According to the initial plans the major part of the experiments will be carried out by guest scientists from universities and other research establishments. But due to the experience gained with accelerators of a similar order of magnitude one is, however, inclined to prefer mixed teams composed of collaborators of DESY and of guests from other research institutes, so as to ensure a close coordination of the accelerator's operation which is necessary for the realization of the experiments.

6. THE PLASMA INSTITUTE AT GARCHING

Besides the already mentioned institute for plasmaphysics of the Jülich nuclear research establishment the Institute of Plasmaphysics at Garching near Munich–which is a member of the Max Planck Society–may be called the large German centre for fusion research. It is much more than an ordinary institute; it is a large research centre. The terms "big science" and "national laboratory" are rightly used in this connection, at least with more justification than in any other place in Germany.

Thus, this "institute" does not only comprise three experimental departments but also a theoretical division and a division for technology. By the completion of the first development stage (1965/66) some 800 to 900 people will be employed at this centre. At present, there are 500. The investments under this first development stage will probably amount to DM 93 million, to which the Bund is contributing approximately two-thirds and the European Atomic Energy Community one-third. Current expenditure on personnel and operation amount to DM 11 million in 1964 and are expected to reach DM 20 million in 1966. The Bund, the German Laender, and the European Atomic Energy Community will each raise one third of the total cost.

In January 1961 an association contract was concluded for three years, which provided for a total expenditure of DM 30 million necessary for the realization of the joint research programme. This contract is expected to be prolonged to the end of 1964, the total expenditure being increased accordingly, and after that it will probably be continued by the regular contracts which at present the European Atomic Energy Community is aiming at within its member countries under its association agreement with the five large national centres for nuclear fusion. The laboratory halls, workshops, study rooms for theorists, library, lecture-hall, and rooms for the huge electronic computer already completed cover an area of more than 15,000 sq. m.

The activities of the Garching institute extend to numerous branches of plasmaphysics. It must be mentioned, however, that the search for new experimental methods for the production of hot and dense plasmas –some of these methods have been known since the Second Geneva Conference of 1958–is given less priority than the development of new measuring techniques, the experimental handling of individual problems, and progress with regard to a better theoretical understanding of the plasma. Among others the Garching institute is concerned with the following special fields of plasma physics research:

fast discharge with theta-pinch,
linear z-pinch and tubular pinch;

stationary plasmas under low and high pressure;
plasma diagnostics, among others by means of Laser-rays;
magnetohydrodynamics and microscopic theory of the plasma.

As against the normal structure of an institute of the Max Planck Society with only one director at the top –the scientific administration of the Institut für Plasmaphysik GmbH is the responsibility of a Board of Directors which is composed of the directors of the institute's five departments together with the two directors of the Munich Max Planck Institute for Physics and Astrophysics, Werner Heisenberg and Ludwig Biermann.

To sum up, it may be said that as far as Germany's research centres are concerned the largest gaps are bridged, and it has been possible during the last years–taking into account at least the facilities still under construction and the projects to be realized in the near future–to lay the foundations–not so much on a wide but solid basis–for the future activities. Thus, the German Atomic Energy Programme states: "Due to the efforts made in Germany in recent years, attractive employment opportunities again exist in various branches, a new generation of well trained scientists has been educated, and some of the results of research work performed here have found international recognition." Yet in the following sentence the German Atomic Energy Programme utters a warning against being satisfied with the results achieved so far: "However, a severe backlog is evident in numerous fields. The task ahead now is not only to make up lost ground but also to keep pace with the ever increasing efforts of other countries in basic research. Leadership in nuclear engineering cannot be imagined without the country holding a leading position also in the domain of fundamental scientific knowledge. Progress made in any of these areas will in the long run turn out to have a great bearing on technology and engineering."

V. REACTOR DEVELOPMENT AND ITS LIMITATIONS

–A survey of industrial activities–

The exploitation of nuclear energy undergoes four stages: basic research, applied research, development, and technical realization. Thus, it will hardly do to specifically promote only basic research or even applied research without making available the results thus obtained to development and technical realization in some form or other. There is no doubt that, as is stated in the German Atomic Energy Programme: "Leadership in nuclear engineering cannot be imagined without the country holding a leading position also in the domain of fundamental scientific knowledge." But on the other hand the public has a right to expect that every opportunity is taken to transform the progress made in research into a reasonable technological lead of the home industry. An industrialized country such as the Federal Republic of Germany has to be active on all levels of nuclear development, last but not least in the field of technical progress.

In the German Atomic Energy Programme these ideas are formulated even more precisely; it says there: "A German reactor development is essential for the following reasons:

1. Judging by the present state of the art, nuclear energy is expected to be introduced as an additional source of energy in power plants during the forthcoming decade. This necessitates preparatory action now, although the Federal Republic has no energy gap forcing the country to initiate the construction of nuclear power plants at once.
2. A highly industrialized country, such as Germany, must in the future be in a position to offer and construct proven types of nuclear power plants to meet the demand at home and abroad.
3. Technological progress, advanced by activities in the nuclear energy field, is imperative to keep up the German industrial standard in competition and in co-operation with other countries, and in many sectors of industrial manufacture. In this way, promotion of nuclear energy by the government is apt to constitute a general means of ensuring that the competitive ability of German products is retained."

The executive organ responsible for the technical realization of the exploitation of nuclear energy–actually the development of power reactors–is industry. In a highly-industrialized country we may confidently leave the initiative for reactor development to industry and to the electricity supply companies. What the Federal Republic of Germany has so far done in this field and what is still forth coming will be set out below. It is true that most of the important power reactor projects were already mentioned in another context, but on account of their great number it is necessary to summarize them systematically. The reactors are classified according to their different coolants and or moderator materials so that this classification is only to some extent identical with that of the Atomic Energy Programme which proposed a classification accordingly to reactor construction series. The latter will be discussed hereafter.

1. FROM THE BOILING WATER REACTOR TO THE SUPERHEAT REACTOR

With a view to producing competitive nuclear power the water reactors are today considered the most promising. In the Federal Republic this trend of development is above all pursued by the AEG (Allgemeine Elektrizitäts-Gesellschaft) which started as the German partner of General Electric and which, in the meantime, has become an independent supplier. The first step on this way was the establishment of the experimental nuclear power plant at Kahl on the Main which was constructed in co-operation with General Electric and Hochtief AG. This reactor operates on the boiling water principle in a direct loop with natural circulation. The net output of the nuclear power station amounts to 15 MWe., and from the start of power operation in June 1961 to the beginning of March 1964 the electric power output amounted to more than 200 million kilowatthours. The second step is the construction of the big nuclear station at Gundremmingen which is joint venture of AEG, General Electric, and Hochtief AG. The power station will be equipped with a twin-loop boiling water reactor with a net output of 237 MWe. The construction company and operator is–as in Kahl–a joint subsidiary of RWE and Bayernwerke AG. Early in March 1964 AEG and Vereinigte Elektrizitätswerke Westfalen AG (VEW) founded the Kernkraftwerk Lingen GmbH with a view to construct and operate a 250 MWe. nuclear power station under the German Atomic Energy Programme, with a boiling water reactor at Lingen in the Land Lower-Saxony. In the secondary circuit this power station will be equipped with an oil or gasfired superheater which increases the power station's output by 90 MWe. and which supplies live steam at temperatures equal to those of conventional thermal power stations.

Under the development programme for a new integrated boiling water-superheat reactor with homogeneous fuel elements, AEG was granted permission to install an experimental loop generating superheated steam into the reactor of the Kahl nuclear power station. Consequently the plant had to be shut down for sometime. In this experimental loop nuclear superheat was produced for the first time in Europe in December 1964. This development aims a superheat prototype reactor which will be set up in the immediate neighbourhood of the Kahl experimental nuclear power station. The decision on this project will be forthcoming in the course of the summer of 1964, so construction may begin late in 1964. The electric output will amount to 35 MW. in the second stage of construction.

The core of the AEG superheat reactor will consist of 2,880 tubular fuel elements which are grouped in 45 fuel element bundles. The individual tubular element contains enriched uranium dioxide sealed within an outer and an inner shell tube. The energy released in the fuel as a result of nuclear fission partly reaches the outer and partly the inner surface of the fuel element tube. The water, being also the moderator, is evaporated on the outer surface and superheating of the steam, which is achieved during four passages through the core, is effected on the inner surface. The saturated steam produced at the outside is then passed through a steam drier and is led into the core after passing a mixing collector and the fuel element connection tubes. The superheat finally leaves the reactor pressure vessel through four nozzles. During the first development stage the prototype reactor station produces secondary superheat in steam converters; this superheat drives a conventional turbine. During the second development stage of this plant it is intended to install a superheat turbine which is directly connected to the radioactive steam. For safety reasons the reactor pressure vessel is surrounded by a second tank, a so-called pressure shell. In order to prevent pressure from forming in this shell, the steam which might discharge in case of leaks is passed into a water basin, where it condensates. Heat generation is controlled by 32 control rods which in case of danger are hydraulically injected into the core. According to date given by AEG heat consumption, i. e., fuel material consumption per generated kilowatthour, is reduced by approximately 20 per cent as against large-scale superheat plants with boiling water systems. Due to steam superheating the specific steam consumption goes down to approximately 65 per cent, so that investment costs may also be expected to go down.

AEG is no longer the only German firm to be engaged in the development of water reactors. Siemens-Schuckertwerke, which up to now have been concerned with the development of ship propulsion reactors, are now highly interested in pressurized water reactors which will be built in co-operation with the U.S. firm of Westinghouse. Thus Siemens has carried out the design work for an Austrian 15 MWe. prototype nuclear power plant and for a 240 MWe. nuclear power station on behalf of a south-German consortium; both power stations are equipped with pressurized water reactors.

The construction of the so-called advanced pressurized water reactor (FDR) by Arbeitsgemeinschaft Babcock/Interatom for the German nuclear merchant ship is part of the development of water reactors. The integrated method of construction applied in this case may gain considerable importance for stationary reactors, too.

2. HEAVY WATER-NATURAL URANIUM REACTORS–ALSO WITH GAS COOLING

During the 1950's, it was quite natural for a country owning no isotope separation plant, to use natural uranium as fuel in its own nuclear power development. For obvious reasons the Federal Republic of Germany, too, orientated its own reactor development towards the use of natural uranium. But since this fundamental question was not discussed before 1955, the gas-cooled graphite-moderated natural uranium reactors do not appear to be very attractive any longer, and thus only the heavy water-moderated natural uranium reactors came into question. Due to its unrivalled neutron economy heavy water provides the best prerequisites for a promising reactor type, particulary with a view to high conversion radio. Since enriched uranium may be expected to be readily available at a moderate price for quite sometime to come, a low enrichment of the buclear fuel is preferred because of a higher power density and therefore the reduced investment costs. In principle, all of these reactors can also operate on natural uranium, taking in account, however, a corresponding rise in costs, such as of fuel element canning.

In the German Federal Republic this trend of development is pursued by Siemens-Schuckertwerke AG. At present, this firm is building the multi-purpose reactor on behalf of the Karlsruhe nuclear research centre. It is a reactor of the pressure vessel type, the core of which is housed in a pressure vessel, such as in H_2O-water reactors. Construction of this vessel gives rise to minor problems only, and reduces the reactor's maximum output at least as long as low enriched fuel is used.

Therefore, Siemens-Schuckertwerke AG have tuned to the development of a second D_2O-type, namely to the pressure tube reactor. Each individual fuel element is fitted into a separate tube absorbing the pressure coolant, and it seems possible–at least theoretically–to arrange any number of pressure tubes side by side. Thus the maximum reactor output is no longer limited by the dimensions of a pressure vessel which it was not possible to build. At the same time it is possible to separate the moderator from the coolant, and almost any coolant may be used independently of the D_2O-moderation. The choice of the maximum coolant temperature is also no longer limited. Thus Siemens envisaged for its AKB-project, developed on the basis of a heavy-water pressure tube reactor and named after its purchaser, the Atomkraft Bayern–CO_2-gas as a coolant. Its outlet temperature is so high that the live steam temperature of this 100 MWe. power station reaches 527° C, at a pressure of 103 atm. abs. However, the D_2O-moderator surrounding the pressure tubes heats to 60 to 70° C only.

Contrary to the French and Canadian designs of the same type the 351 cooling channels are arranged vertically. Within the fission zone they consist of 2.7 mm. thick Zircaloy. Heat insulation in the interior of the pressure tubes is effected by two thin stagnant CO_2-gas layers which are limited inwards by an insulating tube. The top and bottom extensions of the cooling channels consist of steel pipes. They are tightly rolled into the Zircaloy tubes.

The AKB pressure tube reactor is controlled by raising and lowering the moderator level. Emergency shutdown is effected in the same manner by opening several valves of large cross-sections.

To this and the heavy water is kept at an elevated pressure of a helium gas atmosphere. The rods of the fuel elements contain UO_2 pellets of slightly-enriched uranium in thin-walled steel tubes. The uranium enrichment, it is true, brings fuel costs up by about 20 per cent but increases burn-up by almost 50 per cent, i. e., from hardly 6,000 MWd/t. to 11,600 MWd/t. And in spite of the enrichment it seems economically reasonable to write off, to store and "forget about" the depleted fuel elements, regardless of the fissionable material they still contain. The AKB-project will have a burial ground to take up all depleted fuel elements accumulating over 20 years of reactor operations. The charging machine is designed so as to have access to each of the hot channels during operation and after opening of the high-pressure shutter, in order to re-arrange or change the fuel elements, which consist of 19 fuel rods each. A graphite container makes for the mechanical resistance to the fuel elements standing vertically in the hot channels.–Design of this project was completed in spring 1963 and the construction decision is expected to be forthcoming in summer 1964.–Whatever arguments might be advanced against heavy water reactors with a view to the present state of fuel element development, the fact remains that Canada, France, Sweden, India and Switzerland continue heavy water-natural uranium reactor development and even Britain has recently started to develop a reactor on the basis of heavy water.

3. ADVANCED HIGH-TEMPERATURE REACTORS

The AKB pressure tube project already demonstrated that, now as before, it is attractive to use gas as a heat carrier in reactor construction. The same applies to graphite which is not only characterized by very favourable nuclear properties but also by an unusual temperature stability. Thus graphite gas reactors are still very attractive, provided that the nuclear fuel to be used is not natural uranium which entails relatively high investment charges. The picture changes completely as soon as higher U-235 enrichments are used. Therefore, the development of the graphite gas reactors tends rather towards high-temperature reactors.

As far as the Federal Republic of Germany is concerned mention should be made above all of the AVR experimental nuclear power station which is being set up on the site of the Jülich nuclear research establishment by Arbeitsgemeinschaft Brown/Boveri/Krupp-Reaktorbau. The core of the high-temperature reactor used in this power station is simply a pile of graphite fuel element balls which are held together by a graphite-coated container having the form of a blast furnace shaft. Operational temperatures of the pile of spheres, which is cooled by a flow of helium gas, are such as to produce superheated steam of more than 505° C atmospheres gauges in the steam generator above the core. The reactor core, the cooling-gas blowers and the steam generator are all arranged in one and the same steel tank which is surrounded by a second container–the so-called safety container. This reactor block, together with the charging machine for exchanging and moving the fuel element balls and all gas carrying components of the helium cycle, are housed in the protective containment of the reactor building which is surrounded by a 1.50 m. thick concrete shield. The reactor buildings and the turbine plant are separated from each other and connected only by a channel for pipe-lines and cables. Reactor output is controlled by changing the cooling gas flow, this being done by a cooling gas blower with a controlled turnover rate. Control of the secondary steam cycle corresponds, in general, to the system applied in conventional power stations.

As earlier mentioned, considerable delays were incurred in the construction of this 15 MWe. nuclear power station, not only for technical reasons but also for organizational difficulties. The initial doubts of experts that it would be impossible to fabricate fuel element balls of sufficient impermeability and good mechanical and technical properties do no longer exist. It will therefore be possible to simplify the design of future reactors of this type and thus to reduce costs.

Of course, the BBC/Krupp-Reaktorbau-GmbH people began early to wonder how to continue this development. There are two possibilities:

1. development of a large power station with an electric output of 200 to 250 MWe., using if possible the thorium-uranium fuel cycle;
2. development of a small, i. e., compact, reactor for ship propulsion or for use in other non-stationary plants, with the direct inclusion, if possible, of a gas turbine in the cooling circuit.

Both approaches are tried. The first one is taking shape already in the THTR development project of Jülich nuclear research establishment. The second approach will be realized under the development programme for advanced reactors of low and medium power, and is called "Gasturbinen-Hochtemperaturreaktor" (GHR) (gas turbine high-temperature reactor). Owing to the fact that the cooling gas directly propels a gas turbine and does no longer have to be converted into steam to produce power, it is possible to make full use of the thermo-dynamic advantages of high-temperature development.

Gutehoffnungshütte AG chose similar approaches, also relying upon a gas turbine closed cycle. Their graphite-moderated reactor of the HTGR type uses fuel elements of quite a different type and the reactor design is therefore different. A rod-type ceramic fuel element, in which graphite serves as moderator, canning, fuel matrix and structural material, is characteristic of this development. The fissile material is highly enriches uranium 235. Thorium is used as fertile material. Both these materials are in the form of carbide particles having a diameter of 150 to 400 μ. Their cladding material is pyrolytic carbon which largely delays the release of radioactive fission products. The particles are imbedded in a graphite matrix. As opposed to fuel elements in metal canning no hermetic inclusion of all fission products is obtainable if these fuel matrixes are used. In order to prevent contamination of the primary circuit a sweep gas flow, which is separated from the main circuit, is passed through the interior of the fuel elements and carries off the fission products released by the fuel. The sweep flow passes through a fission product absorber in the interior of the fuel element and then arrives at a gas purification plant outside the reactor pressure vessel. There, the remaining fission products and impurities are removed. The coolant used is helium.

Operational conditions of the HTGR are characterized by the fact that the fuel elements have a surface temperature of 1000° C and the cooling gas a temperature of up to 750° C. Thus steam temperatures are obtained similar to those of modern conventional power plants. By dispensing with the metal cladding of the fuel element, the nuclear fuel is more efficiently utilized and a rather low parasitic neutron capture accounts for the high conversion ratio. The result should be very long usage times of the fuel elements and low fuel costs. On behalf of a group of German utilities, Gutehoffnungshütte, in co-operation with the American firm General Atomic and Siemens-Schuckertwerke, prepared an offer for the conventional part of a 40 MWe. power station of this type to be erected probably at Wiesmoor. Due to the participation of General Atomic it is possible to make use of the experiences gained in the construction of the American HTGR reactor at Peach Bottom.

Gutehoffnungshütte is, for the time being, developing and designing a 25 MWe. plant with beryllium as moderator, and a gas turbine in a closed circuit. The plant is to be a compact gas-cooled reactor of low and medium power. The reactor core of the prototype plant consists of hexagonal beryllium oxide slugs. The fuel is a mixture of uranium oxide and beryllium oxide, and the elements are clad with stainless steel. In spite of its conservative design the reactor obtains a power density of approximately 15 MW. per cubic metre. The outlet temperature of the cooling gas is 650° C and, given a thermal output of 75 MW., a net efficiency of 33 per cent is obtained. The title on design of this project is scheduled for completion in late 1965.

The third firm concerned with the development of high-temperature reactors in the Federal Republic of Germany is Babcock and Wilcox with their advanced gas-cooled reactor (FGR). The development of this reactor type is in line with the British AGR, the well-known "Advanced Gas Cooled Reactor", at Windscale. However, the FGR is an advanced version, its integrated design being the main difference to the other plants of that type. Reactor core, steam generator and blowers are all housed in a cylindrical pressure vessel. This reactor type is also under consideration for the Wiesmoor project.

4. SODIUM REACTORS, THE PREDECESSORS OF THE BREEDER REACTORS

Whoever seriously engages in the fast breeder business intends to make these reactors economically attractive for power production has, under the prevailing circumstances, to pay attention to sodium cooling. Superheated steam cooling, it is true, is also being considered for the Karlsruhe breeder project, but there are still some unsolved probleme to it. Sodium cooling, however, is known to work well even at a high power density and to remove reliably the heat from the core.

Thus, the Karlsruhe nuclear research centre takes a great interest in the plan to set up the KNK prototype reactor of Interatom in the immediate vicinity of Karlsruhe. The sodium cooling of this reactor would offer the Karlsruhe breeder group the possibility of carrying out those experiments and tests for which the Rapsodie reactor at Cadarache in France is beiing built. The compact sodium-cooled reactor of the 20 MWe. experimental power station set up under the programme of advanced reactors of low and medium power would be an ideal test reactor for mass testing of fuel element needles to be used in future breeder fuel elements. The KNK reactor has the same specific power density per kilogramme of fuel as has the Karlsruhe fast breeder which is to be built later on, so that the heat transfer could be continuously tested under more or less true breeder conditions.

In the same way one could systematically select suitable alloys for the canning of fuel element needles and test the efficiency of the fission gas plenum in the upper end of the fuel element tubes. If the burn-up of the breeder fuel elements is in the order of magnitude of 100,000 MWd./t. as is planned, a considerable amount of fission gases are produced, resulting in a pressure load on the fuel element needles which might become dangerous. In order to reduce this gas pressure, fuel element pins outside the reactor core will be equipped with voids where fission product gases can gather, provided, however, that the fission product gases can diffuse through the nuclear fuel at a reasonable speed. Therefore, it is necessary to find out whether the burn-up causes a porosity large enough to let the fission products pass into the void, the so-called fission gas plenum.

The reactor core of the planned KNK reactor is contained in a steel vessel of 1.9 m. diameter. The sodium coolant flows from bottom to top through the 66 fuel elements in the core. Each element consists of two ring-shaped rows of fuel rods, and the central cylindrical hollow space as well as the ring-shaped interval are filled with zirconium-hydride particles which serve as moderator and remain in the reactor when refuelling takes place. The coolant flow can be individually controlled for each fuel element by means of a controllable collimator. Control rods are on fuel element position. The reflector chosen is a stainless steel blanket of 13 cm. thickness. The two sodium steam generators, of 29 MW. thermal output each, supply superheat of 510° C and 85 atm.

In May 1964 the critical experiment for this reactor was performed at the Geesthacht reactor station. A plant, i. e., a sodium loop for 5 MW. conventional thermal power, is under construction at Interatom and is expected to be taken into operation late in 1964. In this plant large-scale technical experiments are to be performed on reactor components designed for reactors with sodium cooling under conditions similar to actual operation. Thus the comprehensive development and testing programme within the KNK reactor development may well extend into 1965. Simultaneously, construction of the prototype reactor could bei started.

5. REACTOR SERIES

Looking at this broadly planned-power reactor development in the Federal Republic of Germany, one is inclined to call for someone to organize the whole business and to impose certain restrictions. In measure as the reactor building industry depends upon generous governmental assistance to its development projects, the taxpayer demands that only such projects and reactor series are promoted as promise to produce, in the near future, electric power at a price comparable to that of conventional power stations, and thus contribute to making the country's reactor industry competitive on the international market. These problems have been realized, and the German Atomic Energy Programme for 1963 to 1967 contains some criteria for the restrictions that are imperative and will probably be imposed.

In this connection the German Atomic Energy Programme emphasizes the idea of reactor series.

It says there:

"German efforts should aim at reactor types which are considered promising now or in the near future, and these types should be realized step by step. This means that, of a particular reactor type a range of successive units is constructed which gradually increase in capacity, are then improved by further development, reach a higher degree of technical perfection, and will thereby operate more economically as time progresses.

In cases where an economical reactor type already proven abroad is concerned, such a reactor construction range will demand comparatively little development work, commence with large-capacity units, and require only a small amount of promotion by the Government. In contrast therefore, a construction range based on a new reactor type which does not operate economically consumes a large amount of development expenditure. It must start off with small-capacity prototype reactors, and will not be feasible without considerable public funds."

According to the Atomic Energy Programme, selection of the reactor types for any construction range should be governed by the following criteria:

1. The reactor type must show prospects of producing electrical power economically in the near future and of becoming competitive over a longer period of time. In this context, the possibility of incorporating improvements as a result of foreseeable advancements will have great bearing. For judging the economics, the fuel cycle must be considered under a long-term aspect. In particular, the heavy investments for reprocessing

irradiated fuel and the cost of re-using the recovered fissionable material in thermal reactors has to be examined.

2. The reactor project must make use of available international experience.

3. It must be ensured that development and construction of the reactor are performed by an efficient German industrial group. If a project is undertaken in co-operation with a foreign group it must be made sure that the German group is awarded a substantial share of the work, especially of the nuclear portion of the plant to be constructed, and that the German group will continue to participate actively in any further development work.

4. Reactor types which by their new design promise to be an important German contribution to the development of nuclear reactors, may for this very reason be granted preferential promotion at least during the early stage of development. In event of the requirements set out above being met, reactor types with good conversion properties should be given preference with a view to improved utilization of the nuclear fuel and to the breeder reactors scheduled for construction later. The same applies to reactors with high coolant temperatures and process steam pressures since they permit the use of novel turbine generators and have a high fuel utilization because of their increased efficiency.

The German Atomic Energy Programme also refers to the extent that Government assistance is required and states:

"The reactor construction ranges to be selected are expected to require extensive initial promotion by the government, at least where reactor types not yet proven are concerned. In particular, the substantial cost of an extensive development associated with a successful reactor design can by no means be borne solely by the reactor engineering firms, in the light of the restricted market which will exist for such plants initially. The power utility companies, as the purchasers and operateurs of such reactors, are expected to ask for compensation of the conceivable operating losses and of the operational risk involved.

As the units constructed within such a range are improved, the financial support by the Government can be gradually reduced and ultimately discontinued altogether.

The initiative for development along the lines indicated can be left largely to industry and the power utilities. However, public promotion should be granted only to projects which meet the listed criteria."

With the same object in mind, however with a slight shift of emphasis, the State Secretary of the Federal Ministry for Scientific Research, Wolfgang Cartellieri, some time ago described the problem of promoting nuclear industry. In the Taschenbuch für Atomfragen 1960/61 he wrote: "Taking into account the future importance of nuclear energy to economy, there is a strong public interest in the development of a German nuclear industry. Therefore, the Government cannot leave this development to itself, but has to pursue an active policy of promotion, and it has to see that private enterprise enters this new field with the necessary farsightedness. Today, the development and construction of power reactors and other nuclear installations are still linked with a great many uncertainties concerning costs and require enormous funds which in no country can be raised by private industry alone. In the Federal Republic, too, the government must give financial support to the development of a nuclear industry. The amount of money which must be made available must not disguise the fact that only initial aids can be granted to develop and support this new branch of industry as long as reactor plants are not yet competitive. In the long run, German nuclear industry, too, will have to live up to the principles of a free market economy and will have to make major contributions of its own."

Finally, let me quote the resolution of June 1963 of the German Atomic Forum with regard to the implementation of the German Atomic Energy Programme by industry: "If German industry is to remain competitive, it is now imperative to gain the necessary practical experience in the construction and operation of nuclear power stations without delay. However, it appears that if this object is to be achieved, the system of Governmental promotion measures so far applied needs some modification. The Forum fully backs the envisaged more vigorous concentration and tighter coordination of research and development work."

The present atomic energy development in the German Federal Republic centres round two main points: Government promotion measures must be intensified, and reactor development must concentrate on a limited number of reactor types. It is true that it has proved to be an advantage from the very beginning that nuclear power development in Germany has not been restricted to a single line of development.

Looking across the German frontiers we discover that other countries do not find it at all easy to give up the restrictions they initially imposed upon themselves by sticking to one or two reactor types. On the other hand, a country like the Federal Republic cannot afford such multifarious development as the U.S.A., and even there one can observe a certain trend towards restriction. But concentration of the industrial activities alone does not suffice, nor does the demand, however justified it may be, that the government should do more to promote German nuclear industry.

6. FUEL ELEMENT AND MEASURING INSTRUMENT FABRICATION

Just as a large automobile company cannot exist in the long run, if it is unable to develop and build the engines which it installs in its cars, the development of an efficient national reactor industry seems to be jeopardized if it has to rely on fuel elements fabricated by other countries. A large reactor builder may even think of affiliating a fuel element manufacturing plant to his enterprise. Generally, however, it is most helpful to have the special enterprises of the chemical and metallurgical industry at home to do the job.

In the Federal Republic of Germany there is such a special enterprise, i. e., NUKEM (Nuklear-Chemie und -Metallurgie GmbH = nuclear chemistry and nuclear metallurgy). In 1960 NUKEM was founded by DEGUSSA which had taken up nuclear development activities as early as in 1955. Apart from DEGUSSA, the companies Rio Tinto Zinc of London, Mallinckrodt of St. Louis (U.S.A.) and Metallgesellschaft of Frankfurt are associated of NUKEM. Today NUKEM employs more than 400 people and utilises a total working area of about 7,700 square metres.

At first DEGUSSA (and later NUKEM) was mainly concerned with the fabrication of nuclear fuel, but then the field of activity was extended to the development and fabrication of fuel element plates, fuel element pins and complete fuel elements; some of these activities were carried out by NUKEM alone, others in co-operation with reactor builders. For example, the first additional charge of fuel elements for the reactor of the Kahl experimental nuclear power station was supplied by a consortium of AEG and NUKEM. NUKEM fabricates the fuel rods, which are then assembled into fuel element bundles by AEG.

In addition to fuel element fabrication, development work plays an important part at Wolfgang near Hanau, where NUKEM has its factories. It has been calculated that development work alone accounted for about half of the productive working hours in 1963. Thus, contracts are awarded by the European Atomic Energy Community, the Federal Ministry for Scientific Research and, last but not least, the reactor industry. Thus by way of sub-contracts NUKEM is taking part in the development of fuel and fuel elements for the high-temperature reactor of BBC/Krupp Reaktorbau GmbH, the superheat reactor of AEG and the advanced gas-cooled reactor of Babcock.

For the fast breeder project NUKEM was offered a special opportunity of getting familiar with plutonium fuel element fabrication. Not less than 175 kg. of plutonium have to be manufactured into oxide cakes for the Karlsruhe SNEAK project. To this end ALKEM was founded as a subsidiary of NUKEM and Dow Chemical

Company in spring of 1964. Dow, which holds 30 per cent of the shares, possesses wide experience in plutonium manufacture, an experience that is now made available to ALKEM, and argumented by sending American experts to Karlsruhe, where ALKEM will take up production as subtenant of the nuclear research centre in the laboratories for hot chemistry which have just been completed.

On the whole, a subcontractor like NUKEM is not in an easy position in a country like the Federal Republic of Germany, because the company has to compete with industries in Western Europe which benefit to quite some extent from previous national development and production orders or which, in general, can rely upon a fairly large production for other industrial branches at home. So as not to lose an order, German enterprise, therefore, must often accept orders the payment of which will no longer cover the costs incurred. On the other hand, NUKEM will certainly not be the only company in the nuclear energy business including some subcontractors to be in the red.

In addition to the comparatively small number of reactor builders there is, of course, a larger number of enterprises having concentrated on particular fields of nuclear energy development or supplying conventional components which, however, have to meet the higher standards of nuclear engineering. It would lead nowhere to list all such enterprises. Special mention will only be made of the manufacturers of measuring devices and instruments.

Frieseke & Hoepfner, for example, have for 15 years done development work to set up a wide-ranging industrial programme for nuclear instruments, making it possible to solve the most different and complicated problems. Apart from many standard devices, the programme includes combinations of single parts according to the international 19 inch type of construction. In 1964 a complete programme for fully transistorized components was established. Detectors range from the Geiger Müller miniature counter tube to the large-volume scintillation counter. Five types of automatic sample changers are produced to automize laboratory work. Apart from these production items, special monitoring devices and special equipment have been developed for some nuclear research centres.

Siemens & Halske AG, to take another example from the measuring instrument industry–is a subcontractor for neutron flux measuring channels and radiation monitoring devices for the instrumentation of reactors and laboratories. In this connection not only nuclear projects of Siemens-Schuckertwerke are concerned, but also those of other companies. The same applies to Telefunken, a subsidiary of AEG.

However, the German Atomic Energy Programme also alludes to the fact that the measuring instrument industry in the Federal Republic is in a true state of emergency, and it says that in many cases where nuclear energy is applied in research and technology the expenditure on measuring devices were the major portion of the total cost; that these devices were mostly obtained from abroad and only a small portion was produced by German industry; that the dependence on other countries was hampering the expansion in other fields of technology. There was, therefore, an interest in encouraging the development of measurement engineering by granting Government promotion to industry or by having development work performed in research centres which would then have the device manufactured by industry under a licence.

VI. HOW WILL DEVELOPMENT CONTINUE?

–Retrospective survey and outlook on the future–

If, in the northern part of the Netherlands you pass the enclosing dam the Dutch built to separate the former Zuyder Sea from the North Sea you will come across a memorial tablet where the dam was closed in 1932, with the following words: "A people that lives builds for the future." We in Germany have hardly any area which lends itself for draining. Yet, the motto is certainly true of our industry, whose ability to export must be maintained and extended, and perhaps this motto will one day be written on the memorial tablet of a German nuclear power station or nuclear research centre. This would at least be justified.

We, in Germany, have come to be sensitive to big words mainly because they were often misused in our country. Thus, nuclear development in the Federal Republic takes place without any pathos, and is observed critically and with scepticism rather than theatrical enthusiasm. If there is a thrill of joy it will most certainly be on the side of an engineer or a scientist and concern a new insight or a novel design. For the rest, criticism is prevailing.

In fact, it happens now and again that something is done in the Federal Republic in nuclear research and nuclear technology which is disappointing, and often it is even more disappointing if nothing at all happens. But do we, the immediately concerned, often tend not to overestimate the disappointments? Looking back on what has been achieved in the Federal Republic since 1955–the important developments have been outlined in this report–one cannot help paying an tribute to the work done. Is it not astonishing that scientists and design engineers of competing companies get together in the German Atomic Energy Advisory Committee, talk about their plans, consult each other and then take a decision jointly? And is it not quite a novel and very positive trend of our social system that in this field the Government has assured the role of a colleague and partner? And if it is true that progress in the fields of science and research is possible only in an atmosphere of freedom, such freedom exists in the Federal Republic of Germany with regard to the utilization of nuclear energy, perhaps to a larger degree than anywhere else, except for the United States.

It was, no doubt, very depressing that the development of nuclear research and technology had such a late start in the Federal Republic. On the other hand, this backlog has been an advantage in that it helped us to avoid sidetracks. When we took our fundamental decisions we could refer to a more advanced state of general knowledge. Later on, one often complained–and certainly with some justification–that the government did not readily decide on the construction of a particular reactor project. Looking back, however, we may say that nevertheless somethings have been realized and that it did pay–at least in one case–to have been so cautious. This is true of the OMR type nuclear power station project in the Stuttgart area which had been developed to a point where the construction decision was forthcoming. Whoever is a protagonist of advanced technology must always accept the risk that a very expensive project may turn out a clear failure. However, only the export is aware of this danger, and, particularly in such a field as the development of nuclear energy, the failure of a big project would have had serious consequences on German public opinion and industry. The delays and initial difficulties encountered in the construction of the FR 2 at Karlsruhe, the research reactors at Jülich and of the AVR pebble-bed reactor have caused some concern, at least to the experts.

On the other hand, one is well aware in the Federal Republic of Germany that the nuclear development of the country has now entered into a decisive phase. Nuclear power production is approaching competitiveness. In the opinion of the European Atomic Energy Community the nuclear power station projects awaiting construction decision will be able to produce a kilowatt hour of electricity at the same price as a modern conventional thermal power station if large units are chosen and if no coal mines are in the immediate vicinity. In nuclear development the Federal Republic has now reached a stage where it is imperative that it decides on the technical realization of some projects, or otherwise all previous afforts may one day prove to have been in vain. The question of whether or not it will be possible to operate a certain reactor type so as to supply a kilowatthour of electricity at a comparable price cannot be answered unless the respective nuclear power station is available: reliable estimates can rarely be made. To this end practical experience has to be gained and proof to be rendered. It is of little aditional value to have a most novel and even economically attractive reactor design if it is not being realized in time. What can the best physician do and of what use is the most refined instrumentation in a hospital, if the patient has died?

Well, utilization of nuclear energy in the Federal Republic has not taken such a bad turn. During the last years something has actually been done to explore the field of nuclear energy, but the interest of technical people, economists and the general public has also been stirred. A real avalanche of development has been set going and in the very near future there will be no more reason to be down-hearted. Do not let us forget that merely 25 years have elapsed since nuclear fission was discovered, and that the utilization of nuclear energy for peaceful purposes started only 10 years ago. Furthermore, the development of nuclear research and nuclear technology has as yet to set the pace for the overall chance which is rooted in the increasing importance of research and science for our civilization–at least in Germany. We live in a hectic time and yet it is impossible to compress a development, which formerly took mankind centuries to accomplish, into a few years. But let us be honest, would life not be dull and boring without such big tasks ahead of us?

VII ACT ON THE PEACEFUL USES OF ATOMIC ENERGY AND PROTECTION AGAINST ITS HAZARDS

(ATOMIC ENERGY ACT)

DECEMBER 23, 1959
(BUNDESGESETZBLATT 1959 I, P. 814)

The following Act has been enacted by the Bundestag, with the consent of the Bundesrat.

PART I
GENERAL

SECTION 1
PURPOSE OF THE ACT

It is the purpose of this Act –

1. to further nuclear research and development and the use of nuclear energy for peaceful purposes;
2. to protect life, health, and property, from the hazards of nuclear energy and from the harmful effects of ionizing radiation, and to provide compensation for damage caused by nuclear energy or ionizing radiation;
3. to prevent danger to the internal or external security of the Federal Republic arising from the use or the release of nuclear energy;
4. to enable the Federal Republic to meet its international obligations in the field of nuclear energy and protection against radiation.

SECTION 2
DEFINITIONS

For the purposes of this Act

1. "special fissionable material (nuclear fuel)" means:
   (a) plutonium 239;
   (b) uranium 233;
   (c) uranium enriched in the isotope 235 or 233;
   (d) any substance containing one or several of the aforesaid substances;
   (e) uranium and substances containing uranium of the natural isotopic mixture of such purity as to enable a continuous selt-sustaining chain reaction to be maintained in a suitable installation (reactor).

   The expression "uranium enriched in the isotope 235 or 233" means uranium containing isotopes 235 or 233, or both isotopes, in such quantity that the ratio between the sum of these two isotopes and isotope 238 is greater than the natural ratio between isotopes 235 and 238.
2. "source material" means:
   (a) uranium containing the natural isotopic mixture, but not falling under paragraph 1;
   (b) uranium containing less than the natural amount of uranium 235;
   (c) thorium;
   (d) any of the aforesaid substances in the form of metal, alloy, chemical compound or concentrate; and
   (e) uranium and thorium ores.

PART II
CONTROL

SECTION 3
IMPORT AND EXPORT

(1) Any person who imports or exports nuclear fuel shall require a licence.

(2) An import licence shall be granted, provided –

1. that there are no known facts giving rise to any doubts as to the reliability of the importer; and
2. that it is assured that the nuclear fuel to be imported will be used in conformity with the provisions of this Act, the statutory ordinances made thereunder, and the international obligations of the Federal Republic in the field of nuclear energy.

(3) An export licence shall be granted, provided –

1. that there are known facts giving rise to any doubts as to the reliability of the exporter; and
2. that it is assured that the nuclear fuel to be exported will not be used in such a way as to endanger the international obligations of the Federal Republic in the field of nuclear energy, or to endanger the internal or external security of the Federal Republic.

(4) Nothing herein contained shall affect any other legal provisions on import or export.

(5) Any other conveyance into or out of the area to which this Act applies shall be deemed to be import or export within the meaning of this Act.

SECTION 4
CARRIAGE OF NUCLEAR FUEL

(1) Any person who carries nuclear fuel outside an enclosed area where nuclear fuel is kept in Government custody, or where activities authorized under sections 6, 7 and 9 are carried on, shall require a licence. Such licence may be granted to the carrier for one specific occasion only. The licence shall be available during the carriage and shall be produced to the competent authority or its duly authorized agents on request.

(2) A licence shall be granted, provided –

1. that there are no known facts giving rise to any doubts as to the reliability of the carrier and of the persons actually effecting the carriage, and that the consignment is accompanied by a person authorized to give instructions, with such expert knowledge as is required for the carriage of nuclear fuel;
2. that it is assured that the nuclear fuel will be carried in conformity with such legal provisions on the carriage of dangerous goods as are applicable to the particular carrier concerned or, in the absence of such provisions, that otherwise every precaution which is necessary in the light of existing scientific knowledge and technology has been taken in order to prevent damage resulting from the carriage of nuclear fuel;
3. that the necessary financial security has been provided to cover all legal liability to pay compensation for damage (sub-section (5) of section 13);
4. that all necessary protection is provided against interference or other intervention by third persons.

(3) For carriage by rail, a general licence shall, on application, be granted to the railway contractor for a period not exceeding three years at a time; provided that the requirements of paragraphs 2 to 4 of sub-section (2) are complied with, that the contractor is reliable, and it is assured that the contractor will cause the carriage to be actually effected by reliable persons. The third sentence of sub-section (1) shall not apply.

(4) Nothing herein contained shall affect any legal provisions relating to carriers in respect of the carriage of dangerous goods.

SECTION 5
CUSTODY, POSSESSION AND OF SURRENDER NUCLEAR FUEL

(1) Nuclear fuel shall be kept in Government custody. Such precautions as are necessary in the light of existing scientific knowledge and technology shall be taken to prevent damage resulting from such custody, and the necessary protection shall be provided against interference or other intervention by third persons.

(2) No person shall be permitted to have nuclear fuel in his immediate possession outside Government custody, unless he –

1. stores nuclear fuel by virtue of a licence granted under section 6;
2. treats, processes or otherwise uses nuclear fuel in an installation licensed under section 7 or by virtue of a licence granted under section 9;
3. carries nuclear fuel by virtue of section 4.

(3) Any person who is in immediate possession of nuclear fuel, without being authorized under sub-section (2), shall surrender it to the custodial authority without delay.

(4) The obligation to surrender nuclear fuel shall cease to apply, if the fuel be transferred to a carrier authorized under section 4 –

1. for the purpose of export licensed under section 3; or
2. for the purpose of delivery to a consignee authorized under paragraph 1 or 2 of sub-section (2).

(5) Nuclear fuel in Government custody under sub-section (1), or in licensed storage under section 6 shall be issued only –

1. where the consignee is authorized to have nuclear fuel in his possession under paragraph 1 or 2 of sub-section (2);
2. where the nuclear fuel is to be carried for the purpose of export in conformity with the provisions of section 4.

SECTION 6
LICENCES FOR STORAGE OF NUCLEAR FUEL

(1) Any person who stores nuclear fuel outside Government custody shall require a licence.

(2) A licence shall be granted if there is need for such storage, provided –

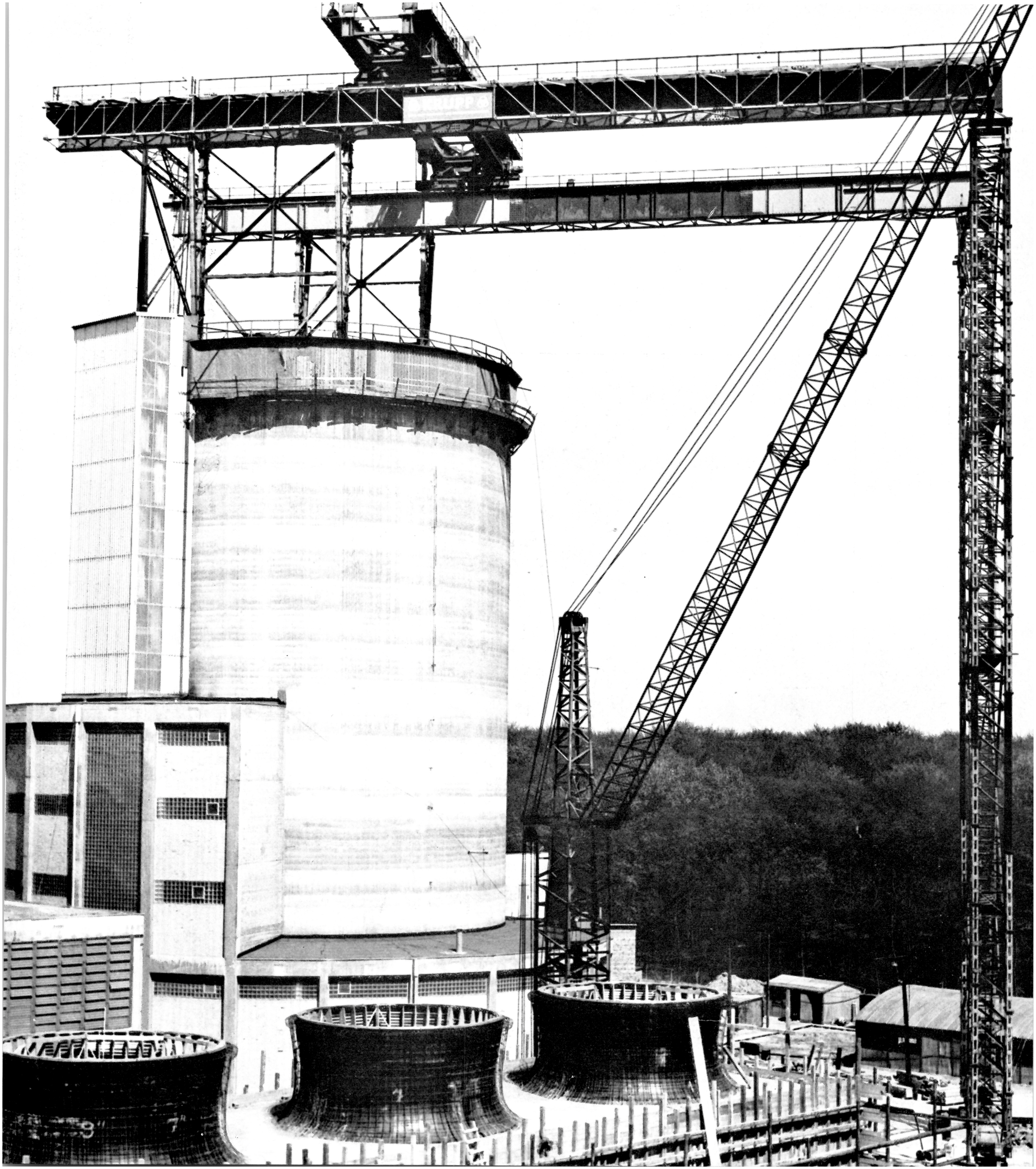
1. that there are no known facts giving rise to any doubts as to the reliability of the applicant or of the persons responsible for the administration and control of the storage, and that the said persons responsible for administration and control possess the requisite expert knowledge therefor;
2. that every precaution has been taken which is necessary in the light of existing scientific knowledge and technology to prevent damage resulting from such storage;
3. that the necessary financial security has been provided to cover all legal liability to pay compensation for damage;
4. that all necessary protection is provided against interference or other intervention by third persons.

SECTION 7
LICENCES FOR INSTALLATIONS

(1) Any person who erects, operates or otherwise holds any installation for the production or fission of nuclear fuel, or for the reprocessing of irradiated nuclear fuel, or who materially alters such installation or its operation, shall require a licence therefor.

(2) A licence may be granted only –

1. where there are no known facts giving rise to any doubts as to the reliability of the applicant and of the persons responsible for the erection, management and control of the operation of the installation, and where the said persons responsible for erection, management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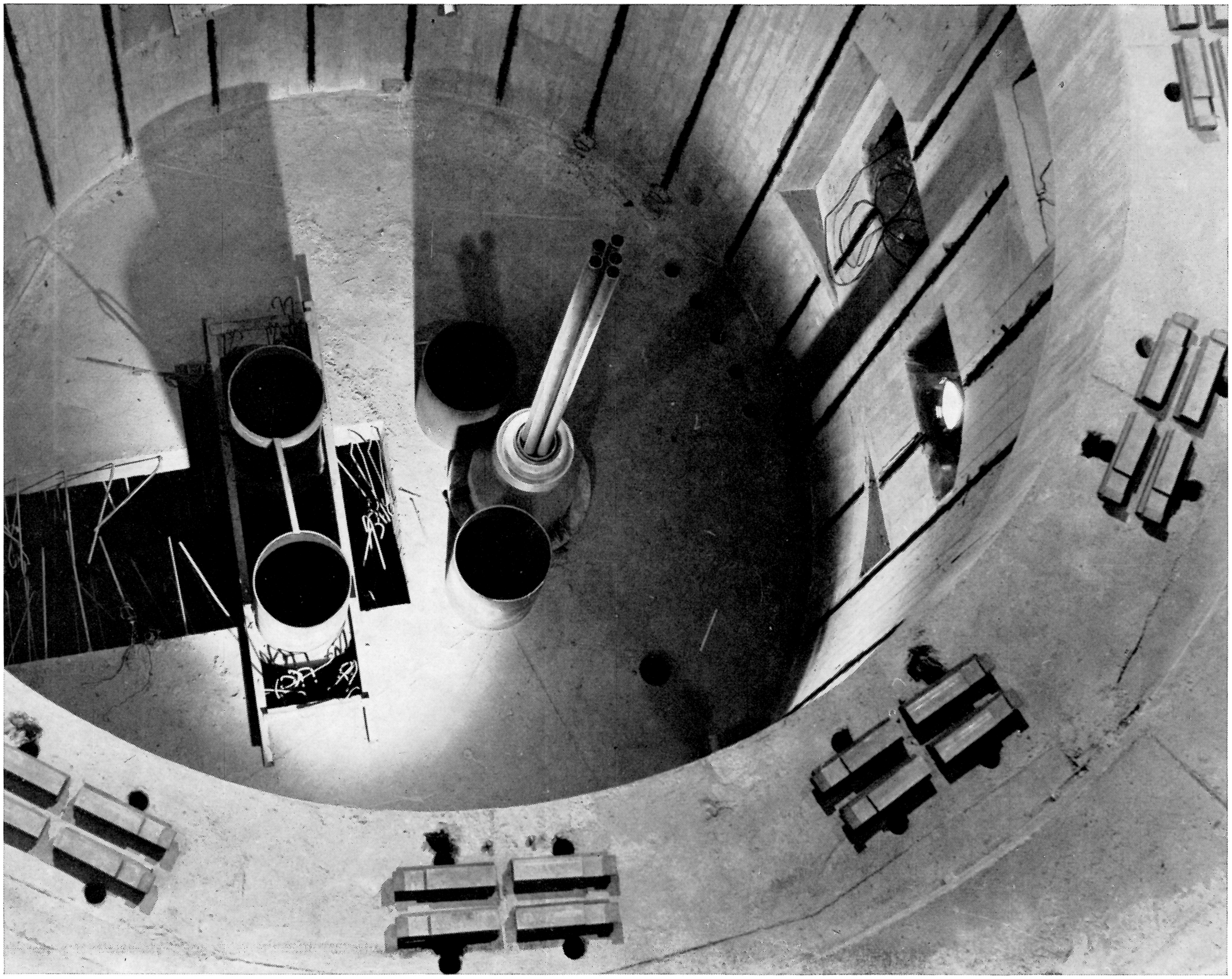
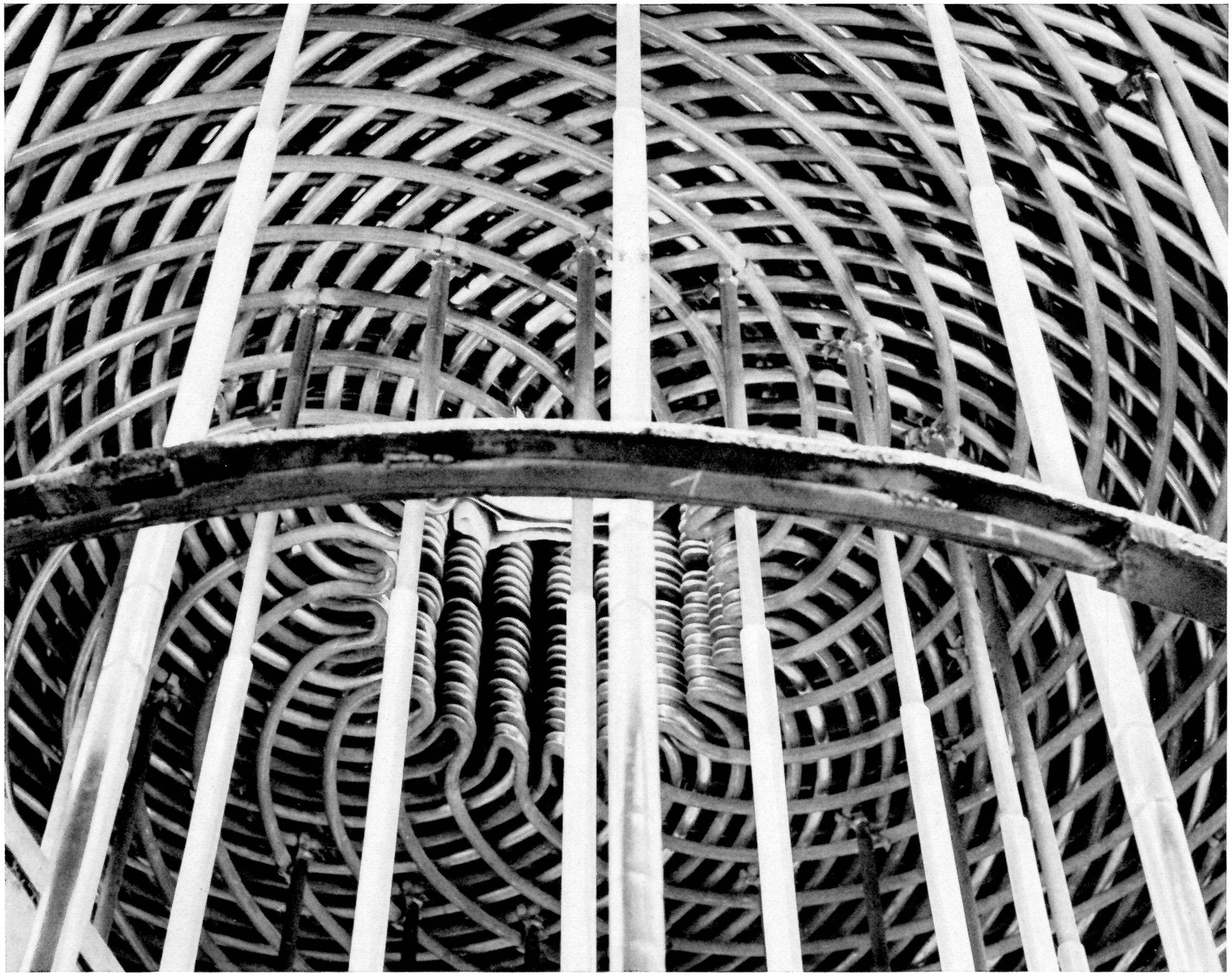
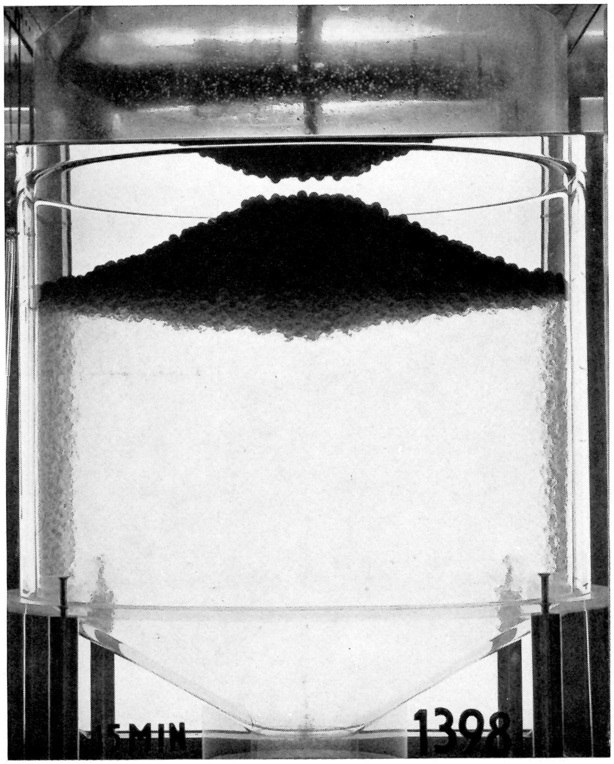


The advanced concept of the pebble-bed reactor is being realized in the form of a 15 MWe experimental nuclear power station at Jülich. The photo on the last but one page shows the construction of the reactor building as of May 1964. The photo on the opposite page shows a segment of the concrete ring on which the reactor vessel will rest and which will house the blowers. The photo on this page is a view of the steam generator located in the reactor vessel immediately above the pebble-bed.

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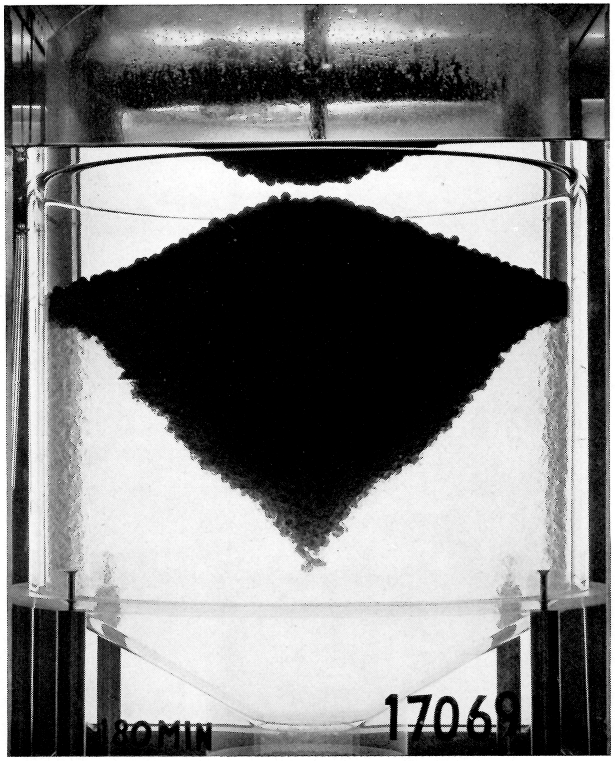
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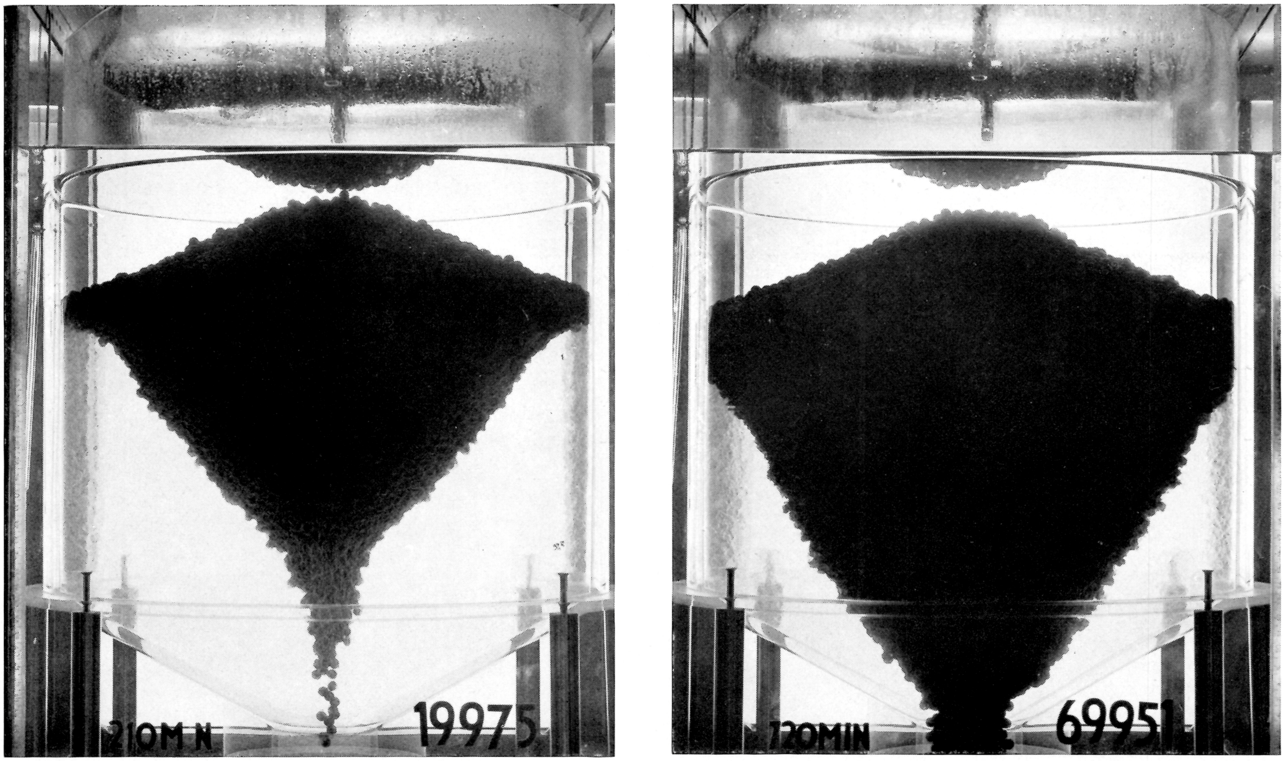
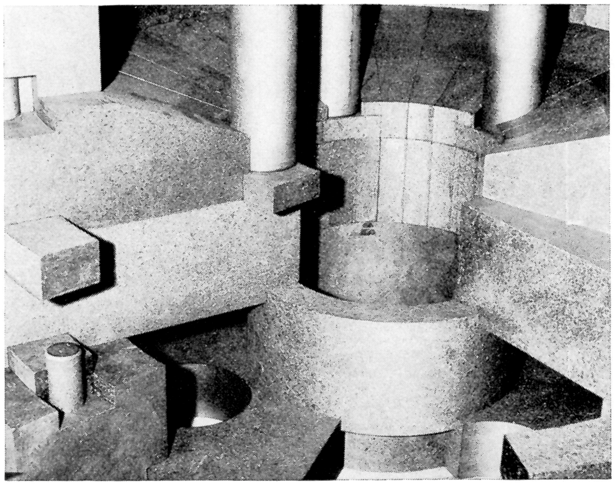
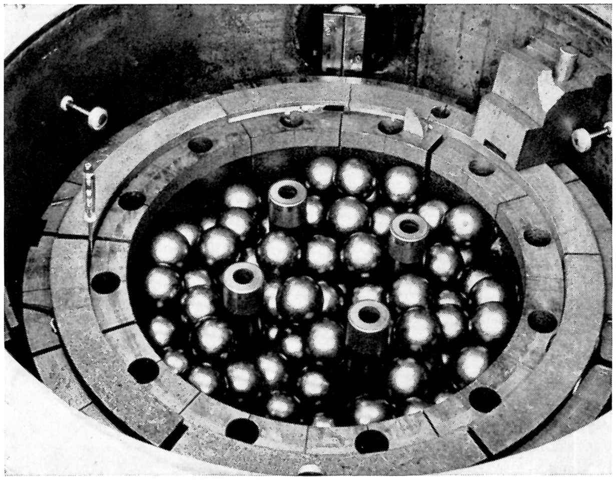
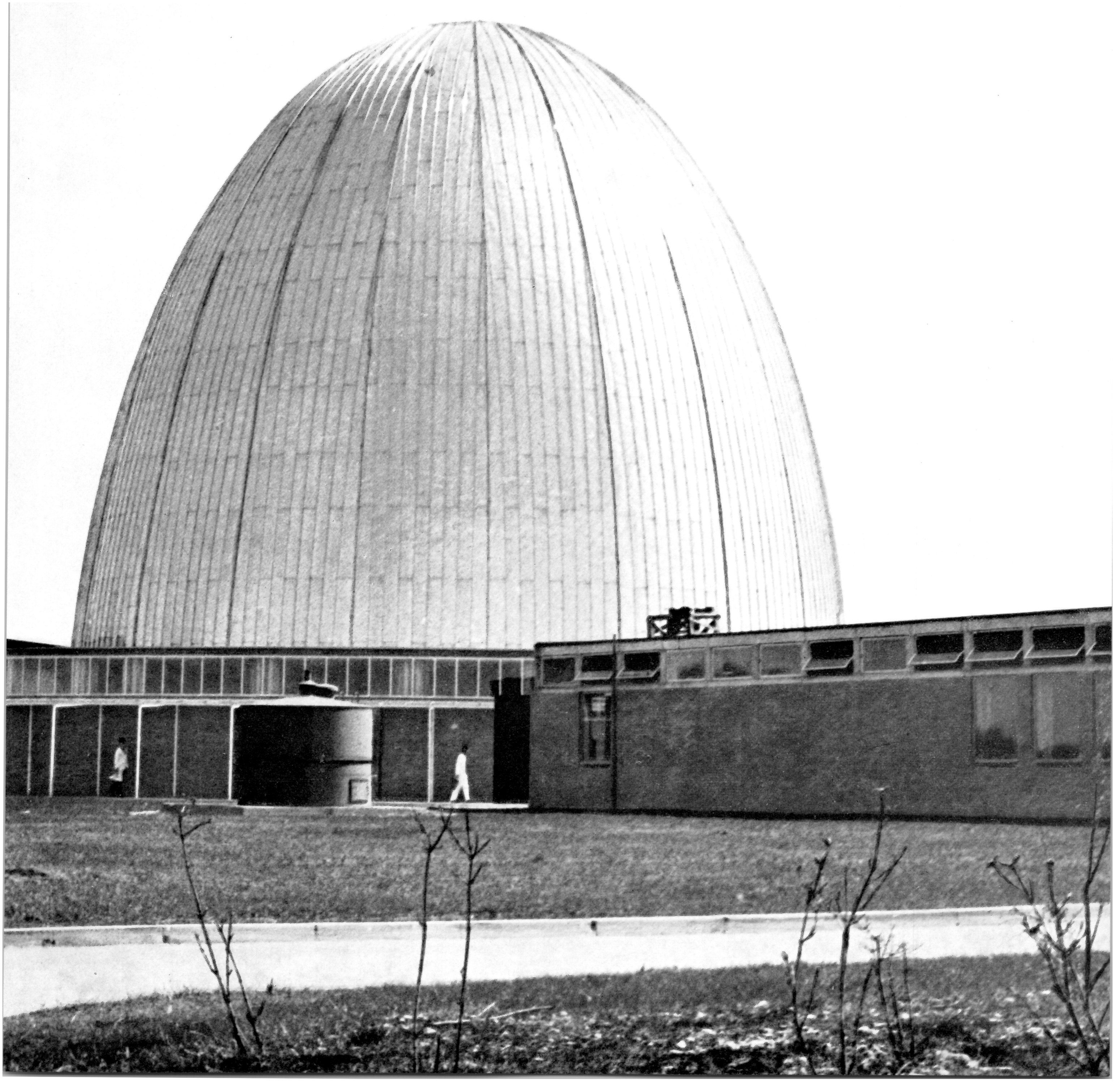


In this experiment which is built to a scale of 1 : 7.5 80,000 glass spheres simulate the flow of spherical fuel elements in the core of the pebble-bed reactor. From left to right the photos show the way of a new charge of coloured spheres through the core in the course of twelve hours.





The concept of the pebble-bed core with its graphite fuel elements lends itself for development of a compact reactor for nuclear ship propulsion or other non-stationary plants; in this case a gas turbine is inserted direct in the cooling circuit. The photo on the upper left shows the structure of the graphite reflector of such a gas-turbine high-temperature reactor, the picture on the left below is the view of its core. Four guiding channels for shut-down rods can be recognized in the centre and the graphite reflector on the outside. The Technical University of Munich was the first German university to get a research reactor. Its egg-shaped reactor hall (picture on the right) – which is, jokingly, called the "atomic egg" of Garching – became the symbol of the activities in nuclear research and nuclear technology that were taken up in the Federal Republic of Germany in the mid-fifties.



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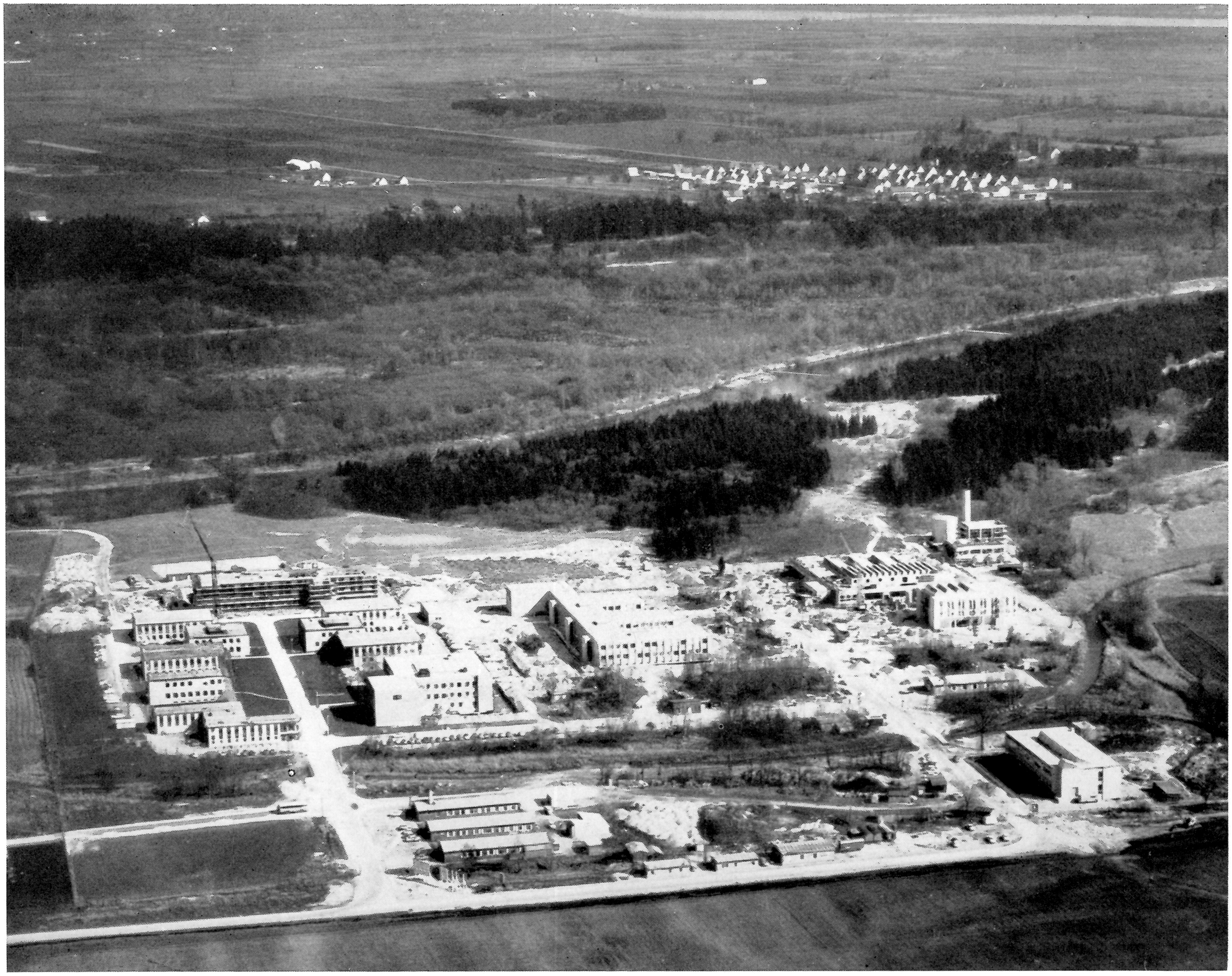
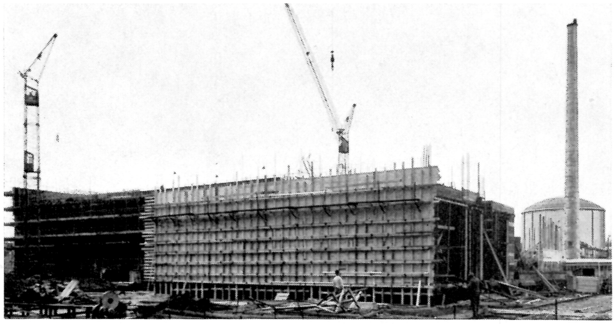
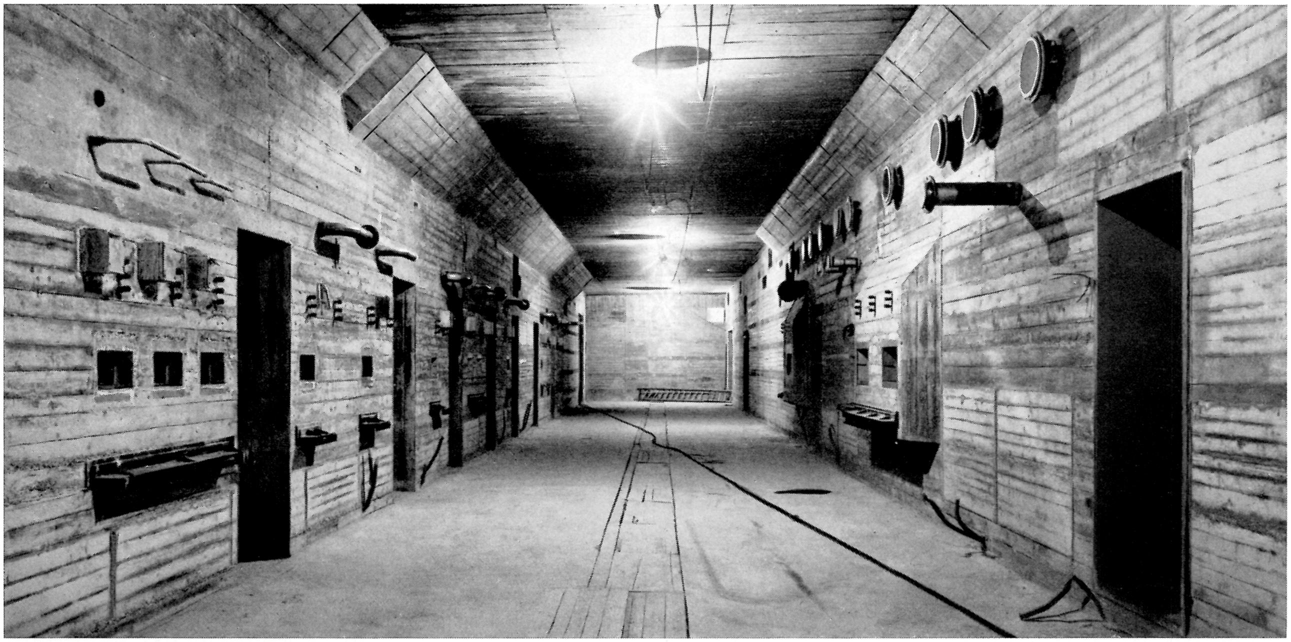
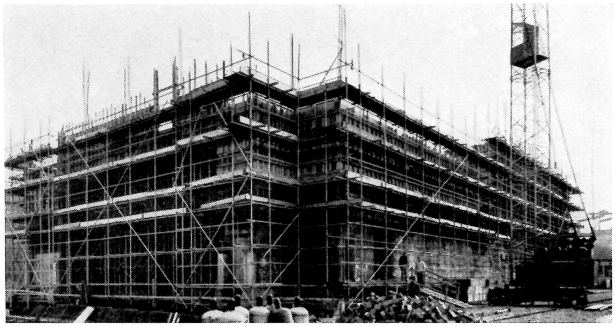
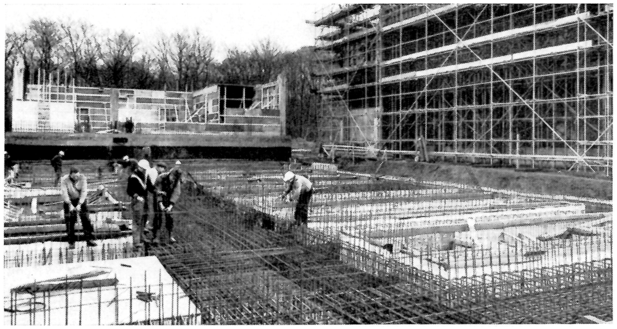


An impressive complex of "hot" cells is being built on the premises of the Jülich nuclear research establishment. The photo in the middle of this page shows the interior of this cell complex under construction, photos below and above give an idea of the various construction phases of the laboratory for radioactive solid bodies at Jülich. – The air-view on the opposite page shows the research facilities of the plasma physics institute. In the front on the right is the laboratory building of the Max-Planck institute of physics and astrophysics.









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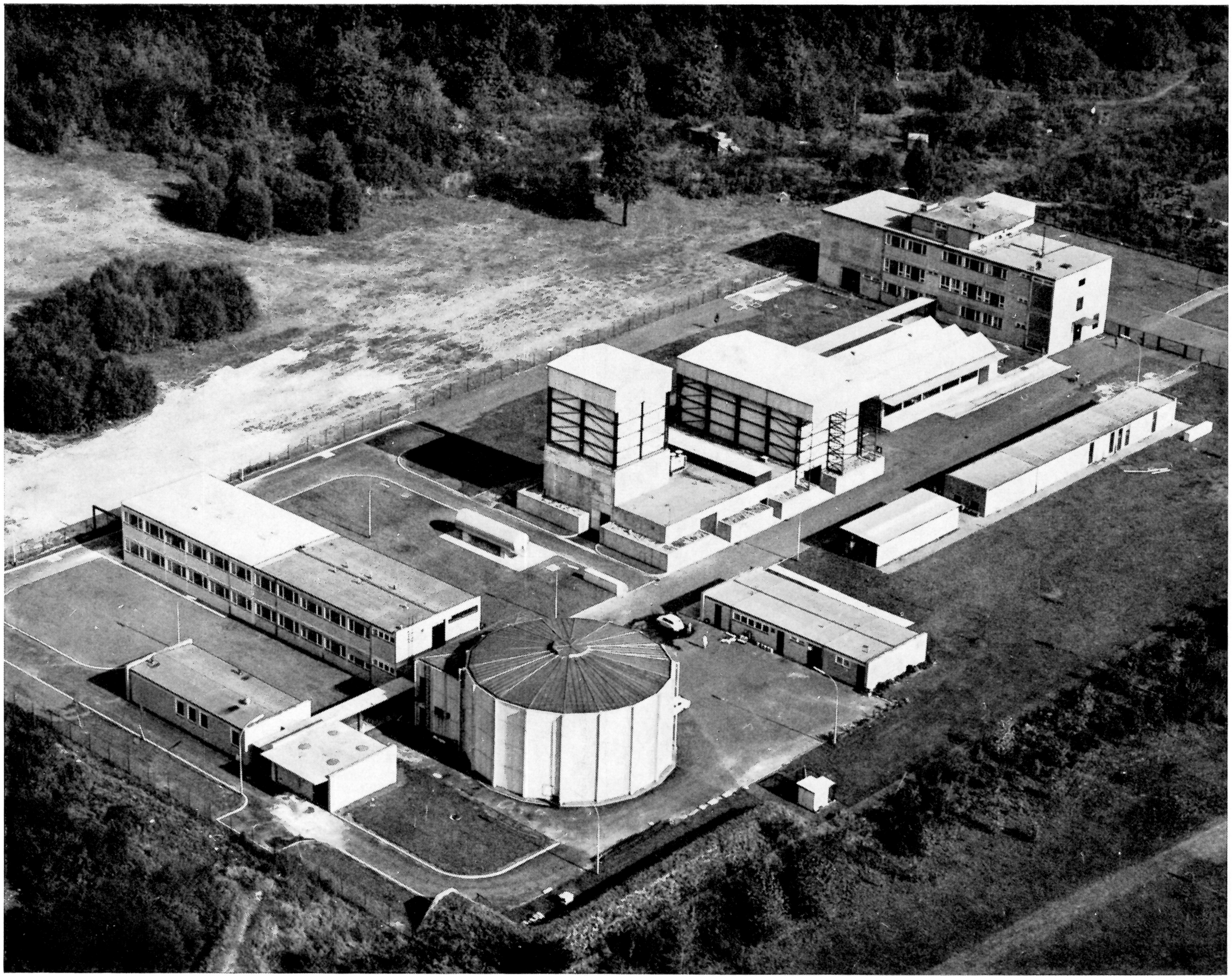
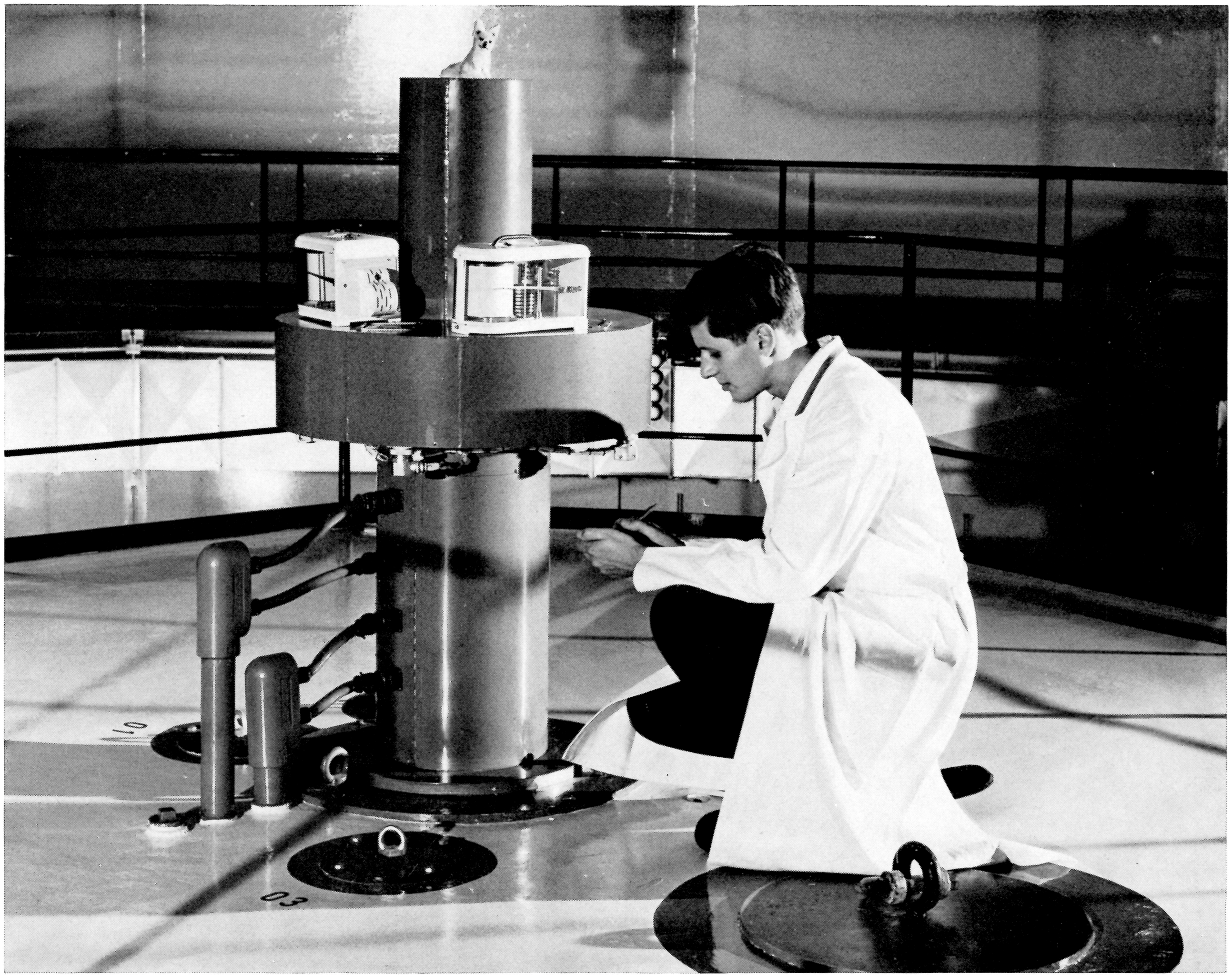
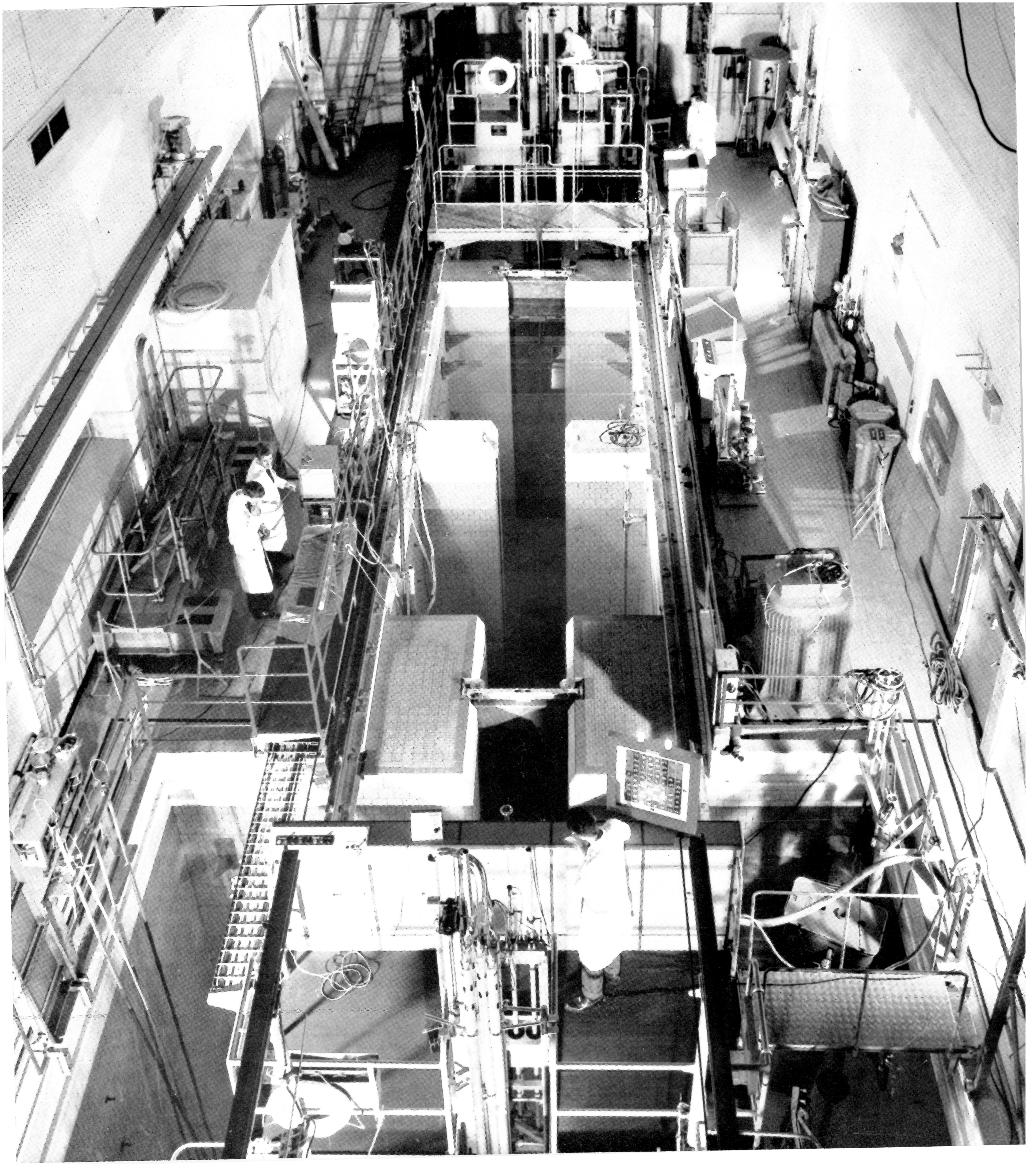
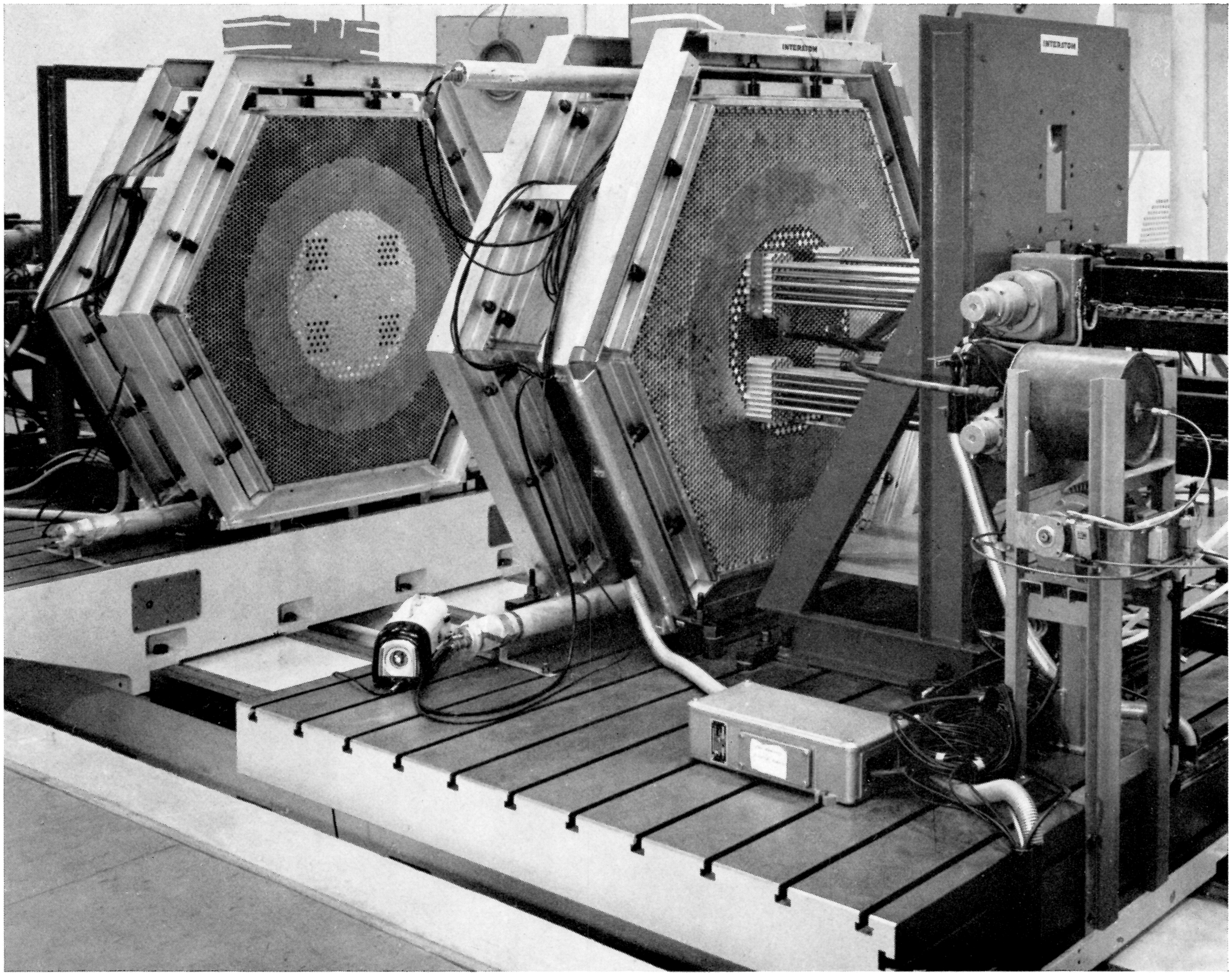


Chemical industry endowed the Institute of Nuclear Physics of Frankfurt University with a homogeneous solution reactor which went critical for the first time on January 10, 1958. On the left: a total view of the institute.





In the Federal Republic of Germany the development of nuclear powered ships is centred in the Geesthacht Reactor Station near Hamburg. The photo on the opposite page is a view of the large reactor hall at Geesthacht, where the two cores of the 5 MWth swimming-pool reactor can be moved into four basins. In addition the Geesthacht Reactor Station disposes of a special experimentation hall where critical assemblies of any kind can be installed. The picture below shows the critical experiment for the KNK experimental nuclear power station.



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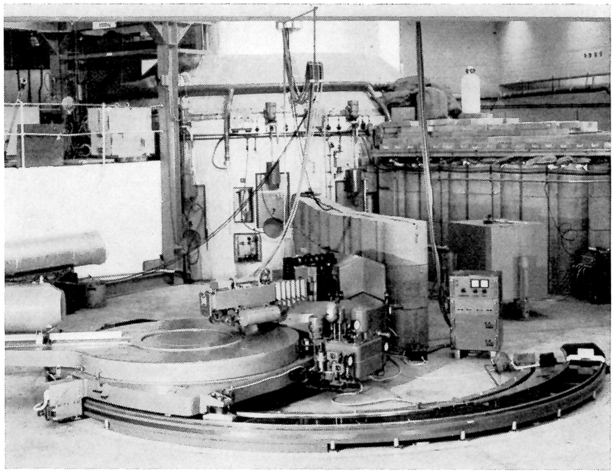
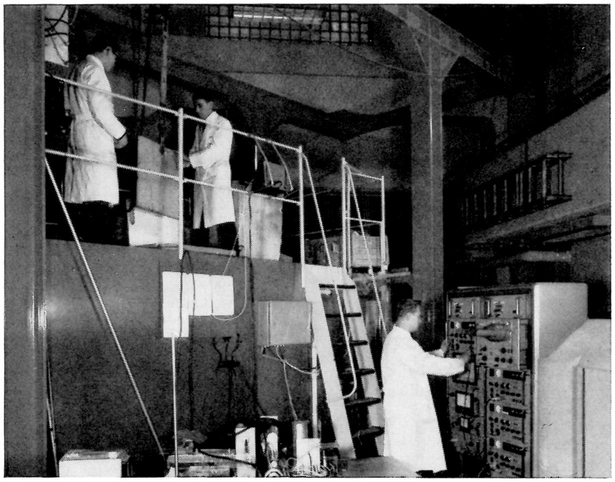
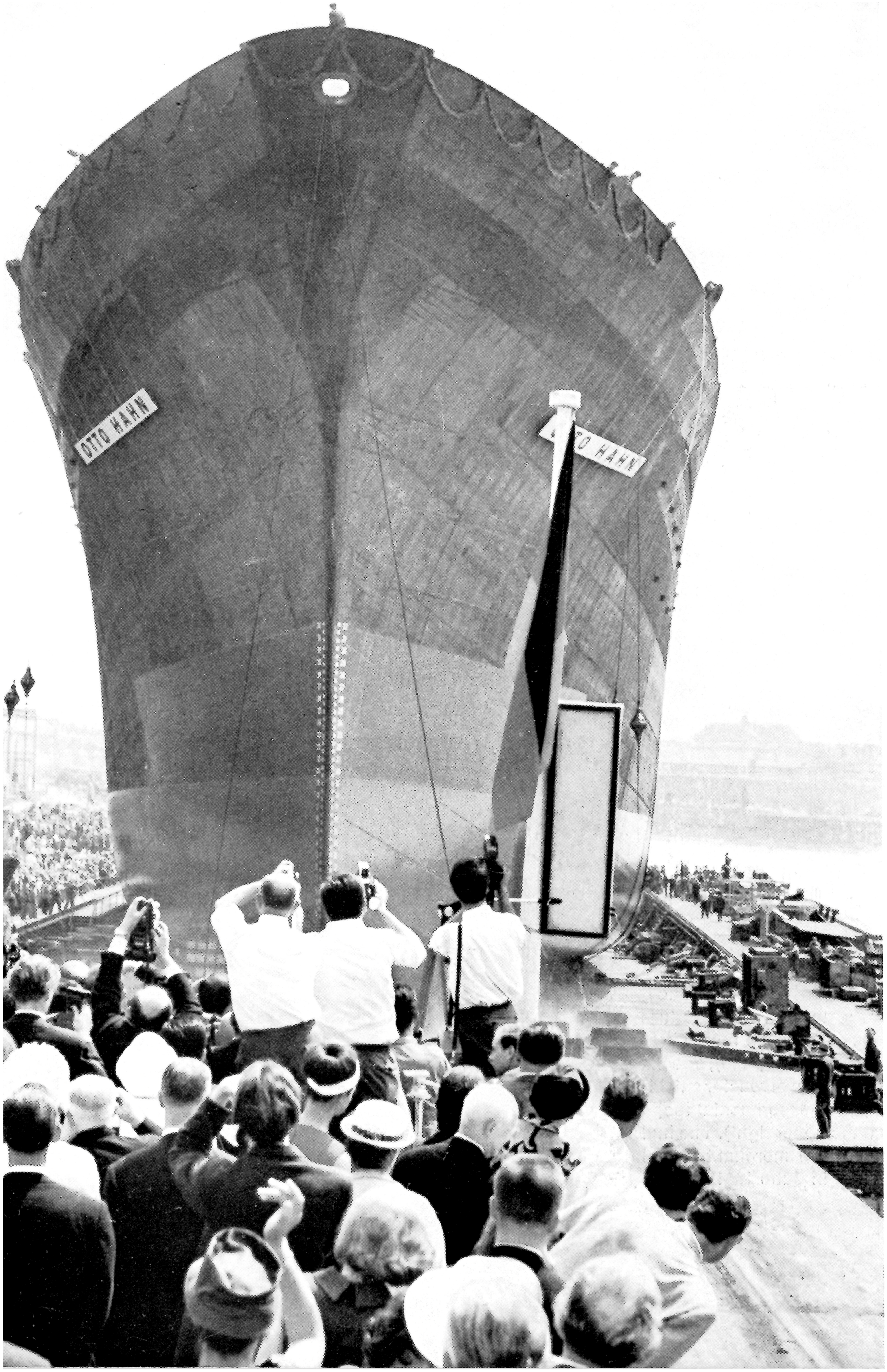




Among the experimental facilities of the Geesthacht Reactor Station there is also a rock-and-roll stand (picture on the left of the opposite page), a neutron monochromator (picture on the right of the opposite page), special experimental equipment for optimization of reactor shieldings (picture on the upper left), and experimental loops for organic coolants (picture on the upper right). The hull of the first German nuclear powered merchant vessel "Otto Hahn" was launched at Kiel in June 1964 (picture on the following page).


OTTO HAHN
OTTO HAHN

and control possess the requisite expert knowledge therefor;

2. where every precaution has been taken which is necessary in the light of existing scientific knowledge and technology to prevent damage resultuing from the erection and operation of the installation;
3. where the necessary financial security has been provided to cover all legal liability to pay compensation for damage;
4. where all necessary protection is provided against interference or other intervention by third persons;
5. where there are no overriding public interests against the particular choice of site for the installation, especially as regards non-contamination of water, air and soil.

(3) All authorities of the Bund, the Laender, and all local authorities and other regional authorities whose jurisdiction is involved shall take part in the licensing proceedings. Where any difference of opinion arises between the licensing authority and any Federal authority concerned, the licensing authority shall apply to the Federal Minister of Nuclear Energy and Water Economy (Bundesminister für Atomkernenergie und Wasserwirtschaft) for instructions. In all other respects the licensing proceedings shall be governed by a statutory ordinance in accordance with the principles of sections 17 to 19 and 49 of the Trading and Industrial Code (Gewerbeordnung).

(4) Section 26 of the Trading and Industrial Code shall apply, as appropriate, if other premises are affected by a licensed installation.

SECTION 8

RELATION TO THE TRADING AND INDUSTRIAL CODE

(1) The provisions of the Trading and Industrial Code regarding installations requiring a licence under section 16 of the Trading and Industrial Code, and concerning prohibition of further operation of such installations, shall not apply to installations for which a licence is required under section 7.

(2) In particular cases, where installations subject to supervision under section 24 of the Trading and Industrial Code are used in any installation requiring a licence under section 7, the licensing authority may grant exemption from the requirements of section 24 of the Trading and Industrial Code, if such exemption is granted with a view to the special technical character of the installation under section 7.

SECTION 9

TREATMENT, PROCESSING AND OTHER USES OF NUCLEAR FUEL, OTHER THAN IN INSTALLATIONS REQUIRING A LICENCE

(1) Any person who treats, processes or otherwise uses nuclear fuel other than in an installation of the kind specified in section 7, shall require a licence. Furthermore, a licence shall be required by any person who applies a method of treating, processing or otherwise using nuclear fuel in a way materially different from that specified in the licence, or who materially alters the installation or its location as specified in the licence.

(2) A licence may be granted only –

1. where there are no known facts giving rise to any doubts as to the reliability of the applicant or of the persons responsible for the administration and control of the use of nuclear fuel, and where such persons responsible for administration and control possess the requisite expert knowledge therefor;
2. where every precaution has been taken which is necessary in the light of existing scientific knowledge and technology to prevent damage resulting from the use of nuclear energy;

3. where the necessary financial security has been provided to cover all legal liability to pay compensation for damage;
4. where all necessary protection is provided against interference or other intervention by third persons.

SECTION 10
EXEMPTIONS FROM LICENSING REQUIREMENTS

To facilitate scientific research and teaching, exemptions from the licensing requirements under sections 3 to 7 and 9 may be granted by statutory ordinance, provided that only small quantities of nuclear fuel are involved, or installations which are not likely to be prejudicial to the purposes of this Act as set out in paragraphs 2 and 3 of section 1.

SECTION 11
ENABLING PROVISIONS (LICENCES, NOTIFICATION, GENERAL PERMITS)

(1) Save where special provision for nuclear fuel and installations within the meaning of section 7 has been made under this Act, it may be laid down by statutory ordinance to enable the purposes specified in section 1 to be achieved: –

1. that prospecting for or handling of radioactive substances (extraction, production, storage, treatment, processing or any other use or disposal), transactions in radioactive substances (acquisition, or delivery to others) or the carriage, import or export of such substances shall require a licence or notification;
2. that the erection or operation of an installation for the production of ionizing radiation shall require a licence or notification;
3. that a general permit may be issued, after examination of the particular type of construction conducted by an authority to be specified in the statutory ordinance, for installations, apparatus and equipment containing radioactive substances or producing ionizing radiation, and such form of notification may be specified as must be given by the operators of the installation, apparatus and equipment.

(2) The statutory ordinance may make the granting of licences and general permits within the purposes of this Act subject to personal and objective requirements, and may regulate the procedure for such licences and general permits.

SECTION 12
ENABLING PROVISIONS (SAFETY MEASURES)

(1) To achieve the purposes specified in section 1, the following may be laid down by statutory ordinance: –

1. the precautionary and supervisory measures which must be taken for the protection of individuals and of the general public in regard to the handling of and transactions in nuclear fuel and other radioactive substances, in the erection, operation and possession of installations as specified in section 7 and paragraph 2 of sub-section (1) of section 11, in the handling of and transactions in installations, apparatus and equipment as specified in paragraph 3 of sub-section (1) of section 11, and in the carriage of such substances, installations, apparatus and equipment;
2. the precautions which must be taken in order to ensure that certain specified radiation doses and concentrations of radioactive substances in air and water are not exceeded;
3. that no person shall be employed in areas exposed to radiation hazards, unless he produces a certificate issued by a specially authorized medical practitioner, and that if any objektions be raised to such employment

for reasons of health, the supervisory authority shall decide after consulting medical experts;

4. that any persons who stay or have been staying in areas exposed to radiation hazards, shall be under obligation to have the radiation doses hat their bodies measured (the extent of such obligation being specified in the statutory ordinance), to undergo medical examination and, in so far as the protection of other individuals or the general public so requires, to undergo medical treatment, such examination or treatment being given by specially authorized medical practitioners;
5. that records shall be kept and reports submitted (in such manner as shall be specified in the statutory ordinance) on the production, extraction, acquisition, possession, delivery and any other disposal of source material, nuclear fuel and other radioactive substances, and on the measurement of doses and dose rates of ionizing radiation;
6. that the supervisory authority shall be given report of any accident or other harmful occurrence during the handling of nuclear fuel or other radioactive substances, during the operation of an installation as specified in section 7 and paragraph 2 of sub-section (1) of section 11, during the handling of installations, apparatus and equipment as specified in paragraph 3 of sub-section (1) of section 11, or during the carriage of such substances, installations, apparatus or equipment;
7. that such radioactive substances as are no longer in use shall be stored, surrendered, disposed of or be secured by the appropriate authority (in such manner as shall be specified in the statutory ordinance);
8. the manner in which nuclear fuel and any other radioactive substances, and installations within the meaning of section 7 and paragraph 2 of sub-section (1) of section 11, shall be protected against interference or other intervention by third persons;
9. that the supervisory authority may issue directions for the execution of any provisions made under paragraphs 1 to 8.

(2) The fundamental right to physical inviolability (first sentence of paragraph (2) of article 2 of the Basic Law [Grundgesetz]) shall be restricted in accordance with paragraph 4 of sub-section (1).

SECTION 13

FINANCIAL SECURITY TO COVER LEGAL LIABILITY TO PAY COMPENSATION FOR DAMAGE

(1) In the licensing proceedings, the public authority shall determine the type, terms and amount of financial security to be provided by the applicant to cover his legal liability to pay compensation for damage. This determination shall be renewed every two years and in the event of any material change in circumstances; the public authority shall prescribe an appropriate time-limit within which the person under obligation to provide financial security must prove that he has done so.

(2) The financial security to be provided in pursuance of sub-section (1) shall –

1. be in due proportion to the hazards of the installation or the activities involving liability under section 25; as a general rule, it should not fall short of the maximum insurance cover obtainable on the insurance market at premiums which are in reasonable proportion to the financial or other interests in the operation of such installation or in the exercise of such activities;
2. ensure fulfilment of the legal liability to pay compensation for damage to an extent appropriate to the particular circumstances in all other cases where, according to the provisions of this Act, or of a statutory ordinance made thereunder, an activity requires a licence.

(3) Within the limits laid down by sub-section (2), and in order to achieve the purposes specified in section 1, more detailes provisions may be made by statutory ordinance as to the measures required to provide financial security to cover legal liability to pay compensation for damage.

(4) The Bund (with the exception of the Federal German Railways [Deutsche Bundesbahn], in the case of carriage in public transport) and the Laender shall not be required to provide financial security. In so far as a Land is liable under section 25, the licensing authority shall determine, with appropriate application of sub-sections (1) and (2) and of the statutory ordinance made in pursuance of sub-section (3), the terms and amount of compensation which, notwithstanding further obligations under section 38, the Land shall pay in fulfilment of the legal liability, without being indemnified by the Bund as provided in section 36. For the application of this Act, the aforesaid liability shall be deemed equivalent to the provision of financial security.

(5) For the purposes of this Act legal liability to pay compensation shall mean the liability to pay compensation for damage as laid down in Civil Law. It shall not include liabilities of the nature specifid in section 903 of the Reich Insurance Code (Reichsversicherungsordnung); but it shall include liability to save harmless in pursuance of sub-section (4) of section 7 of this Act in conjunction with section 26 of the Trading and Industrial Code, and similar liabilities to pay indemnities or compensation, only in so far as the damage or impairment has been caused by an accident.

SECTION 14
FINANCIAL SECURITY AND LIABILITY WITHIN THE MEANING OF SUB-SECTION (4) OF SECTION 13 FOR INCIDENTS INVOLVING LIABILITY UNDER SECTION 25

The special provisions of sections 15 and 16 shall apply additionally to the financial security to be provided in respect of installations and activities involving a liability under section 25.

SECTION 15
THIRD PARTY LIABILITY INSURANCE

(1) Where financial security is provided by means of third party liability insurance, sections 158(c) to 158(h) of the Insurance Contracts Act (Gesetz über den Versicherungsvertrag) shall apply as appropriate. Where sub-section (4) of section 158(c) of the Insurance Contracts Act applies, indemnification by the Bund under section 36 shall not apply. Sub-section (3) of section 156 of the Insurance Contracts Act shall not be applicable.

(2) Third party liability insurance shall cover the legal liability to pay compensation which is incurred as a result of the effects specified in section 25 by persons who –

1. with the consent of the person under obligation to provide financial security, operate, use, or have operated or used the installation, in addition to or in place of such person;
2. being duly authorized, effect or have effected any supply of goods, services or work for the planning, erection, putting into operation, utilization, maintenance or repair of the installation, or for the disposal of waste;
3. have or had been appointed by the person under obligation to provide financial security, or such other person as specified in paragraph 1 or 2, to perform

any act for the planning, erection, putting into operation, utilization, maintenance or repair of the installation, or for the disposal of waste.

SECTION 16
OTHER FORMS OF FINANCIAL SECURITY

(1) Where financial security is not provided in the form of third party liability insurance, but in the form of indemnification or a guarantee furnished by a third person, the provisions of section 15 shall apply correspondingly.

(2) Where financial security is provided in a way other than that specified in section 15 or in sub-section (1) of this section, the person under obligation to provide such financial security shall, notwithstanding section 38, be held liable, if compensation is claimed from such persons as are specified in sub-section (2) of section 15, for damage of the kind specified in section 25, for an amount determined in accordance with sub-section (1) of section 13, and in the same manner and to the same extent as an insurer would be liable under section 15, if the third party liability insurance cover is adequate in accordance with this Act and such statutory ordinances as are made thereunder.

(3) Sub-section (2) shall apply correspondingly to the Bund and the Laender.

SECTION 17
RESTRICTIONS, CONDITIONS, REVOCATION

(1) Licences and general permits granted under this Act or under a statutory ordinance made thereunder shall be issued in writing. They may contain restrictions, and may be made subject to certain conditions, with a view to the purposes specified in section 1. Conditions may subsequently be imposed so far as may be necessary to achieve the purposes specified in paragraphs 2 and 3 of section 1. A time-limit may be imposed on licences other than those issued under section 7, and on general permits.

(2) Licences and general permits may be revoked –

1. where they have not been used within a period of two years, unless otherwise provided in the licence or general permit;
2. where one of their pre-requisites has not existed from the beginning, or has subsequently ceased to exist, and no remedial action has been taken within a reasonable period; or
3. where the provisions of this Act or statutory ordinances made thereunder, or orders or directions issued by the supervisory authorities, or the terms and conditions contained in the notice concerning the licence or general permit, have been seriously or repeatedly violated, or where a condition subsequently imposed has not been complied with and no remedial action has been taken within a reasonable period.

(3) Licences shall be revoked where the financial security provided does not satisfy the requirements of sub-section (1) of section 13, and where the person under obligation to provide financial security fails to furnish proof, within a reasonable period to be fixed by the public authority, that he has provided the financial security stipulated.

(4) Licences or general permits shall also be revoked wherever such revocation is necessary on account of substantial risk to employees, third persons or the general public, and conditions subsequently imposed cannot provide a remedy within a reasonable period.

SECTION 18
REPARATION FOR REVOCATION

(1) Where a licence or general permit granted under this Act or a statutory ordinance made thereunder is revoked, appropriate reparation shall be paid to the licensee.

Where the revocation is effected by the Bund, the Bund shall be liable to pay the reparation; where the revocation is effected by an authority of a Land, such Land shall be liable. The amount of reparation to be paid shall be determined with due regard to the public interest and that of the person concerned, and shall take into account the reasons which have led to the revocation. The reparation shall be limited to the expense incurred by the person affected, or in the case of an installation to the current value of such installation. In the event of dispute as to the amount of reparation, legal proceedings may be taken in Civil Courts.

(2) There shall be no liability to pay reparation –

1. where a holder of a licence or general permit has obtained such licence or general permit by making statements which are incorrect or incomplete in a material particular;
2. where a holder of a licence or general permit, or persons employed by him to carry out activities thereunder, have by their conduct given cause for the revocation of the licence or general permit, in particular, by serious and repeated violation of the provisions of this Act, or of statutory ordinances made thereunder, or of orders and directions issued by the supervisory authority, or of the terms and conditions of the notice concerning the licence or general permit, or by non-compliance with conditions subsequently imposed;
3. where the revocation had to be ordered owing to subsequent exposure of employees, third persons or the general public to serious hazards arising from the installation or activity for which a licence has been granted.

(3) Sub-sections (1) and (2) shall apply correspondingly to conditions subsequently imposed under the third sentence of sub-section (1) of section 17.

(4) Where a Land is liable for reparation, the Bund or another Land shall be under obligation to contribute, according to their respective interests in the revocation, having regard to all the facts. The same shall apply where the Bund is liable to pay reparation.

SECTION 19

GOVERNMENT SUPERVISION

(1) Any handling of or transactions in nuclear fuel or other radioactive substances, the erection, operation and possession of installations of the type specified in section 7 and paragraph 2 of sub-section (1) of section 11, and any handling of or transactions in installations, apparatus and equipment of the kind specified in paragraph 3 of subsection (1) of section 11, as well as the carriage of such substances, installations, apparatus and equipment, shall be subject to Government supervision. In particular, the supervisory authorities shall ensure compliance with the provisions of this Act and of statutory ordinances made thereunder, with such orders and directions as are issued by the supervisory authorities hereunder, and with the terms and conditions of the notice concerning the licence or general permit, and any conditions subsequently imposed. The provisions of section 139(b) of the Trading and Industrial Code shall apply correspondingly to the powers and duties of the supervisory authorities.

(2) Any person commissioned by the supervisory authority, and any expert called in by the said authority in pursuance of section 20, or any person commissioned by other authorities called in, shall at all times have authority to enter places where there are source material, nuclear fuel and other radioactive substances, installations of the type specified in section 7 and paragraph 2 of sub-section (1) of section 11, or installations, apparatus or equipment of the type specified in paragraph 3 of sub-section (1) of section 11, or places where there is radiation

originating therefrom, and to enter places where there is reason to believe that such conditions exist; and such persons shall have authority to carry out all forms of examination necessary for the performance of their duties. They may request the persons in charge, or employees of such places, to provide them with any information that they may require in the course of such examination. Otherwise, section 24 (b) of the Trading and Industrial Code shall apply correspondingly. The fundamental right to inviolability of domicile as laid down in article 13 of the Basic Law, shall be restricted so far as may be necessary for the exercise of these powers.

(3) The supervisory authority may order that a state be discontinued which is contrary to the provisions of this Act or to statuory ordiances made thereunder, or to the terms and conditions of the notice concerning the licence or general permit, or to any condition subsequently imposed, or from which danger to life, health or property might result through the effects of ionizing radiation. In particular, the supervisory authority may order –

1. that safety measures shall be taken, and may specify such measures;
2. that nuclear fuel and other radioactive substances shall be stored, or kept in custody, in a place designatedby it;
3. that the handling of nuclear fuel or other radioactive substances, the erection or operation of installations of the type specified in section 7 and paragraph 2 of sub-section (1) of section 11, or the handling of installations, apparatus or equipment of the type specified in paragraph 3 of sub-section (1) of section 11 shall be suspended temporarily, or permanently, if the requisite licence has not been granted, or if the revocation has been absolute.

(4) Nothing herein contained shall affect the supervisory powers conferred by other legal provisions, or such general powers as result from land legislation.

SECTION 20
EXPERTS

Experts may be consulted by the competent authorities in the licensing and control proceedings in accordance with this Act and such statutory ordinances as are made thereunder. Section 24 (b) of the Trading and Industrial Code shall apply correspondingly.

SECTION 21
COSTS

(1) Fees may be charged, and repayment of expenses claimed, in respect of any licence or general permit issued under this Act or any statutory ordinance made thereunder; such expenses shall include the expenses of any consultation of experts. Fees and expenses shall be paid by the applicant. In so far as objections of third persons to the erection of an installation within the meaning of section 7 have to be examined, such objectors may be charged with any expenses incurred thereby, where the objections are obviously unjustified.

(2) Fees may be charged, and repayment of expenses claimed, in respect of Government custody. Such fees and expenses shall be borne jointly and severally by the person delivering and the person entitled to use the material.

(3) In so far as Government inspection has made it necessary to consult experts, the person subjected to such inspection shall defray such costs as result therefrom.

(4) The expenses of any safety measures or medical examinations carried out under a statutory ordinance made in pursuance of this Act, or any order issued thereunder, shall be borne by the person who, by virtue of this Act or of any statutory ordinance made thereunder, requires a licence for any activity for which such safety measures or medical examination are necessary.

(5) The costs to be charged under sub-sections (1) and (2), the conditions under which exemption from such charges shall or may be granted, and the procedure to be observed in making such charges, shall be governed by statutory ordinance.

(6) To the extent that Land authorities issue licences and general permits under a statutory ordinance pursuant to section 11, the regulations of the Land concerning fees shall apply.

PART III
PUBLIC AUTHORITIES

SECTION 22
COMPETENCE FOR IMPORT AND EXPORT LICENCES, IMPORT AND EXPORT CONTROL

(1) The Federal Office for Trade and Industry (Bundesamt für gewerbliche Wirtschaft) shall decide on applications for licences under section 3, and on the revocation of licences already issued. The same shall apply where statutory ordinances made under section 11 call for import and export licences.

(2) The Federal Minister of Finance (Bundesminister der Finanzen), or the customs authorities appointed by him, and in the free port of Hamburg the Free Port Authority of the Free and Hanseatic City of Hamburg (Freihafenamt der Freien und Hansestadt Hamburg), shall be responsible for the control of imports and exports.

(3) In so far as the Federal Office for Trade and Industry makes any decisions by virtue of sub-section (1), it shall be bound by the technical instructions issued by the Federal Minister of Nuclear Energy and Water Economy, notwithstanding its subordination to the Federal Minister for Economic Affairs (Bundesminister für Wirtschaft) and his powers to issue instructions based on other legal provisions.

SECTION 23
COMPETENCE FOR CUSTODY AND FOR CARRIAGE AND STORAGE LICENCES

The Federal Institute of Physics and Technology (Physikalisch-Technische Bundesanstalt) shall be competent for Government custody of nuclear fuel, for the issue of licences for the carriage of nuclear fuel, for the issue of licences for storage of nuclear fuel other than Government custody, and for the revocation of such licences. In such cases, the said Institute shall act in accordance with the technical instructions issued by the Federal Minister of Nuclear Energy and Water Economy.

SECTION 24
COMPETENCE OF LAND AUTHORITIES

(1) All other administrative functions under Part II and any statutory ordinances made thereunder shall be discharged by the Laender on behalf of the Bund. Control of the carriage of nuclear fuel shall be exercised by such authorities as are normally competent to supervise the carriage of dangerous goods, even if they are not Land authorities.

(2) The supreme Land authorities (oberste Landesbehörden) designated by the Land governments shall be competent to issue and revoke licences under sections 7 and 9. These authorities shall exercise control over installations as under section 7, and over the use of nuclear fuel outside such installations. In particular cases, they may delegate their functions to subordinate authorities. Any complaints against their directions shall be decided upon by the supreme Land authorities. In so far as provisions other than those laid down in this Act confer supervisory powers on any other authorities, such competencies shall not be affected.

(3) In matters concerning the sphere of activity of the Federal Armed Forces (Bundeswehr), the Federal Minister of Defence (Bundesminister für Verteidigung), or the authorities designated by him, shall, in consultation with the Federal Minister of Nuclear Energy and Water Economy, be the competent authority referred to in subsections (1) and (2).

PART IV
LIABILITY

SECTION 25
LIABILITY FOR INSTALLATIONS WITHIN THE MEANING OF SECTION 7

(1) The operator of an installation within the meaning of section 7 shall, subject to section 38, be liable to pay compensation, in accordance with sections 27 to 34 of this Act, for loss of life, personal injury or deterioration of health caused to any person, or for damage caused to property, as a result of any process of nuclear fission carried out in such installation or of radiation from any radioactive substance emanating from such installation or from any equipment or any activity, including waste disposal, in connection with the operation of such installation.

(2) For the application of this Part, damage to property shall also be deemed to exist where the serviceability of property has been impaired by the effects of radiation from any radioactive substance.

SECTION 26
LIABILITY FOR POSSESSION OF RADIOACTIVE SUBSTANCES OR SUBSTANCES AFFECTED BY NUCLEAR FISSION OR NUCLEAR FUSION IN OTHER INSTANCES

(1) Where, in cases other than those specified in section 25, loss of life, personal injury or deterioration of health has been caused to any person or damage has been caused to property through the effects of any nuclear fission process, or of radiation from any radioactive substance, then the holder of such substance affected by nuclear fission, or of the radioactive substance from which the radiation is emitted, shall be liable to pay compensation for such injury or damage in accordance with

sections 27 to 34. There shall be no liability to pay compensation, if the damage be caused by an event which the holder and such persons as are acting for him in connection with the possession could not avoid, even by taking every reasonable precaution under the circumstances, and which is due neither to any defective condition of the safety devices nor to any failure in their performance.

(2) Sub-section (1) shall apply correspondingly where damage of the kind specified in sub-section (1) has been caused by the effect of nuclear fusion.

(3) Any person who has lost possession of the substance, without having transferred it to a person entitled to such possession in accordance with this Act or any statutory ordinance made thereunder, shall be liable as if he were the holder.

(4) The provisions of sub-sections (1) to (3) shall not apply –

1. where the radioactive substances have been applied to the injured person by a doctor, or a dentist, or under the supervision of a doctor or dentist, in the course of medical treatment;
2. where a legal relationship exists between the holder and the injured person under which the latter has accepted the risk associated with the substance.

SECTION 27
CONTRIBUTORY NEGLIGENCE OF THE INJURED PERSON

Where negligence of the injured person has contributed to the injury sustained, section 254 of the Civil Code (Bürgerliches Gesetzbuch) shall apply; in the event of damage to property, the negligence of the person in actual control of the property shall be deemed to be that of the injured person.

SECTION 28
EXTENT OF COMPENSATION IN CASE OF DEATH

(1) In the event of death, compensation shall be made by payment of the costs of any attempted cure, and for such pecuniary loss as has been sustained by the deceased during his illness be reason of loss or reduction of earning capacity, increase of needs or handicap in regard to his career. In addition, the person liable shall refund funeral costs to the person responsible for paying such costs.

(2) If, at the time of the injury, the deceased was, or might have become, legally responsible for the maintenance of a third person who loses this right as a result of the decease the person liable shall pay compensation to such third person, to the extent of the maintenance for which the deceased would have been liable during his expected life. The liability to pay compensation shall likewise exist where, at the time of the injury, the third person was conceived but not yet born.

SECTION 29
EXTENT OF COMPENSATION IN CASE OF PERSONAL INJURY

In the event of personal injury or injury to health, compensation shall be such as to cover medical expenses and the pecuniary loss sustained by the injured person by reason of temporary or permanent loss or reduction of earning capacity, increase of his needs or handicap in regard to his career as a result of the injury.

SECTION 30
PERIODIC PAYMENTS

(1) Compensation for any loss or reduction of earning capacity, any increase of needs or any handicap in regard to the career of the injured person, and any compensation

due to a third person under sub-section (2) of section 28, shall for the future be discharged by periodic payments.

(2) The provisions of sub-sections (2) to (4) of section 843 of the Civil Code, and of paragraph 6 of section 708 of the Code of Civil Procedure (Zivilprozeßordnung) shall apply correspondingly.

(3) Where no security has been required from the person ordered by court decision to make periodic payments, the claimant shall nevertheless be entitled to demand security, if the financial circumstances of the person liable have considerably deteriorated; in the same circumstances, the claimant shall also be entitled to demand an increase in the amount of any security awarded in the judgement.

SECTION 31
MAXIMUM AMOUNTS OF COMPENSATION

The person liable to pay compensation for damage under section 25 or 26 shall be liable to pay –

1. in the event of the death of or injury to a person, in so far as compensation as specified in section 30 is concerned, an annual payment not exceeding DM 15,000;
2. in the event of damage to property, an amount not exceeding the ordinary value of the damaged property plus the cost of protection against radiation hazards originating therefrom.

SECTION 32
LIMITATION OF ACTION

(1) Claims for compensation under this Part shall be barred after two years from the date when the claimant became aware of the damage and of the identity of the person liable and, irrespective of such knowledge, after thirty years starting from the date of the incident which caused the damage.

(2) Where negotiations concerning compensation are pending between the person liable for compensation and the claimant, the run of the limitation period shall be suspended until such time as either party refuses to continue such negotiations.

(3) Otherwise, the provisions of the Civil Code concerning limitation of action shall apply.

SECTION 33
ADDITIONAL LIABILITY

Save as otherwise provided in section 38, nothing herein contained shall affect any other legal provision under which the operator of an installation within the meaning of section 7, or the holder of a substance affected by nuclear fission or fusion, or of a radioactive substance, is liable to a greater extent than under the provisions of this Part, or under which another person is liable for the damage.

SECTION 34
SEVERAL PERSONS LIABLE

(1) Where two or more persons are legally liable as operators of an installation within the meaning of section 7 or as holders of substances affected by nuclear fission or fusion or of radioactive substances, to pay compensation to a third person for damage resulting from the effects of nuclear fission, nuclear fusion or radiation from radioactive substances, the liability and the extent of compensation due from each of the persons liable shall be apportioned between them according to the particular circumstances of the case and, in particular, to the extent to which the damage has mainly been caused by one or the other person. The same shall apply to the liability of one operator or holder towards another, if the operator of an installation or the holder of a substance has suffered damage.

(2) Sub-section (1) shall apply correspondingly where, in addition to the operator of the installation or the holder of the substance, any other person is legally liable for the damage.

SECTION 35
PROVISION OF FINANCIAL SECURITY DURING CARRIAGE

(1) Any person who consigns nuclear fuel or other radioactive substances for carriage (consignor) shall be under obligation to the carrier to provide financial security to cover legal liability to pay compensation for any damage which the carrier or those in his employ may sustain in the course of such carriage, as a result of effects of the kind specified in section 25 or 26.

(2) The type, terms, and amount of such financial security shall be determined according to the provision that the carrier would be bound to make under section 13.

(3) If the consignor be the Bund or a Land, the obligation to indemnify shall take the place of the provision of financial security.

SECTION 36
INDEMNIFICATION BY THE BUND

(1) Where any person under obligation to provide financial security under paragraph 1 of sub-section (2) of section 13, or any person as specified in sub-section (2) of section 15, has incurred legal liability to pay compensation as a result of effects of the kind specified in section 25, the Bund shall indemnify such person against his liability to pay compensation, to the extent that such liability is not covered, or cannot be met by the financial security provided; provided that the requisite licence has been granted, and operation of such installation or performance of such activity has been started by December 31, 1970. Indemnification against liability resulting from an incident causing damage shall be limited to a maximum amount of DM 500 million, less the amount to which the liability incurred is covered, or can be met by the financial security provided.

(2) Indemnification under sub-section (1) shall not apply to liability to pay compensation –

1. in respect of damage to installations or to property, equipment, apparatus or materials of any kind, including nuclear fuel, appertaining thereto;
2. in respect of any damage sustained by the person under obligation to provide financial security, or any person as specified in sub-section (2) of section 15, during operation of an installation or such activity as specified in sub-section (2) of section 15.

(3) Save as otherwise hereinafter provided, sections 34, 62 and 67 and the provisions of Chapter 6 of Part 2 of the Insurance Contracts Act, including provisions on compulsory insurance, shall apply as appropriate.

SECTION 37
APPORTIONMENT

(1) Where legal liability to pay compensation resulting from an incident causing damage is expected to exceed the amount of DM 500 million, apportionment of the moneys available as compensation for damage, and the procedure to be observed therein, shall be governed by an Act and, pending enactment, by statutory ordinance.

(2) The statutory ordinance referred to in sub-section (1) may only make such stipulations regarding apportionment of the moneys available as compensation for damage as are required to avert hardship. Such statutory ordinance shall ensure that satisfaction of the claims of the injured persons as a whole shall not be unduly prejudiced by the satisfaction of individual claims.

SECTION 38

EXCLUSION OF CLAIMS

(1) No compensation in excess of the amount stipulated in sub-section (1) of section 36 shall be paid by virtue of any legal liability to pay compensation for damage which has resulted from such effects as are specified in section 25 and is covered by an indemnification by the Bund.

(2) In the case of damage not covered by indemnification under sub-section (2) of section 36, liability to pay compensation in pursuance of section 25 shall be excluded. Any person under obligation to provide financial security, and the persons specified in sub-section (2) of section 15, can only be made liable by virtue of another legal liability to pay compensation for damage, if the injured person cannot obtain compensation in another way. No consideration will be given to any other possibility of compensation, if a legal claim for compensation against a third person is involved.

(3) The provisions of sub-section (1), and the second and third sentences of subsection (2) shall not apply, where the damage has been wilfully caused by the person liable, or, in the case of a body corporate, by its legal representative in the discharge of his functions.

(4) To the extent that the Bund is liable for damage of the kind specified in section 25, sub-sections (1) to (3) shall apply as appropriate.

(5) Any person entitled under sub-section (3) to compensation in excess of that specified in sub-section (1) may claim such compensation only in so far as he has not yet obtained, or obviously cannot obtain, satisfaction under the procedure specified in section 37.

SECTION 39

EXEMPTION FROM LIABILITY. RECOURSE

(1) Save in such cases as result from application of the provisions already laid down in sub-section (3) of section 36, the Bund shall be exempt from the obligation to indemnify a person who is to be indemnified against liability in accordance with section 36 –

1. where the damage has been wilfully caused by such person or, in the case of a body corporate, by its legal representative in the discharge of his functions;
2. where such person is a national of a foreign state, in respect of which an order to that effect has been issued by statutory ordinance, such order shall only be issued if there be no guarantee of reciprocity;
3. where such person has acknowledged or satisfied a claim for compensation without the consent of the Bund, unless such acknowledgement or satisfaction could not have been refused by him without obvious inequity.

(2) Furthermore, the Bund shall be exempt from the obligation to indemnify the person under obligation to provide financial security in so far as the security provided falls short of the amount determined in pursuance of sub-section (1) of section 13 or fails to satisfy claims.

(3) The Bund may not invoke exemption from liability under sub-sections (1) and (2) as against the injured person.

(4) The Bund shall have a right of recourse against –

1. any person in respect of whom the Bund is exempt from liability, in so far as the Bund has to pay compensation in pursuance of sub-section (3);
2. any person under obligation to provide financial security, in so far as the Bund, in the event of claims against any person specified in sub-section (2) of section 15, has to pay compensation for which the person under obligation to provide financial security is also held liable; but not in excess of the extent to which such person has to provide financial security to cover such liabilities.

(5) Where the Bund is under obligation to indemnify as a

result of the insurer of a person to be indemnified, a guarantor or any other person jointly liable having acknowledged or satisfied a claim for damages without the consent of the Bund, although it was to be expected that the damage would exceed the amount determined in accordance with sub-section (1) of section 13, the Bund shall have a right of recourse against such persons, unless shall have a right of recourse against such persons, unless such acknowledgement or satisfaction could not have been refused by these persons without obvious inequity.

PART V
PENALTIES AND FINES

SECTION 40
CAUSING AN EXPLOSION BY NUCLEAR ENERGY

(1) Any person who causes or attempts to cause an explosion by the release of nuclear energy, and thereby to endanger the life or health of another person, or property of considerable value belonging to another person, shall be liable to penal servitude for a term of not less than five years.

(2) Any person who causes an explosion by the release of nuclear energy, thereby negligently endangering the life or health of another person, or property of considerable value belonging to another person, shall be liable to penal servitude for a term not exceeding ten years. Where extenuating circumstances exist, the penalty shall be imprisonment for a term of not less than one year.

(3) In particularly grave cases, offences under sub-section (1) shall be punishable with penal servitude for a term of not less than ten years, or for life, and offences under sub-section (2) with penal servitude for a term of not less than five years. In general, a case shall be deemed to be particularly grave where the offender has caused the death of another person by his offence.

SECTION 41
MISUSE OF LONIZING RADIATION

(1) Any person who, with intent to injure the health of another person, exposes or attempts to expose such person to ionizing radiation of such kind as will injure the person's health, shall be liable to penal servitude for a term not exceeding ten years. Where extenuating circumstances exist, the penalty shall be imprisonment for a term of not less than six months.

(2) Where the offender exposes or attempts to expose a great number of persons to such radiation, he shall be liable to penal servitude for a term of not less than five years.

(3) In particularly grave cases offences under sub-section (1) shall be punishable with penal servitude for a term of not less than five years, and offences under sub-section (2), with penal servitude for a term of not less than ten years, or for life. In general, a case shall be deemed to be particularly grave where the offender has caused the death of another person by his offence.

(4) Any person who, with intent to impair the serviceability of property of considerable value belonging to another person, exposes such property to ionizing radiation of such kind as will impair the serviceability of the property shall be liable to imprisonment. The attempt shall be punishable.

SECTION 42
PREPARATORY ACTS

Any person who, in preparation for an offence punishable under sub-section (1) of section 40 or sub-section (2) of section 41, produces, imports, obtains for himself or for another person, stores or makes available to another person nuclear fuel or radioactive substances, or such appliances as are necessary for the execution of such offence, or performs an equally dangerous act of this kind, shall be liable to penal servitude for a term not exceeding ten years. Where extenuating circumstances exist, the penalty shall be imprisonment for a term of not less than six months.

SECTION 43
FINES AND POLICE SUPERVISION

In addition to penal servitude or imprisonment under sections 40 to 42, a fine of unlimited amount and subjection to police supervision may be imposed.

SECTION 44
ACTS OF REPENTANCE

(1) The Court may impose a less severe penalty than the minimum laid down in subsection (1) of section 40, and sub-section (2) of section 41, or impose a more lenient kind of punishment, if the offender voluntarily abandons his activity or otherwise averts the danger.

(2) The Court may impose a less severe penalty than the minimum laid down in subsection (2) of section 40, sub-section (1) of section 41, and section 42, or impose a more lenient kind of punishment, or impose no penalty under these provisions, if the offender voluntarily abandons his activity or otherwise averts the danger.

(3) If the danger is averted without the help of the offender, it shall suffice that he has seriously endeavoured to avert it of his own free will.

SECTION 45
PUNISHABLE HANDLING OF NUCLEAR FUEL AND LONIZING RADIATION

(1) Any person who, without such licence as is required under this Act, wilfully –

1. imports or exports nuclear fuel,
2. carries nuclear fuel,
3. stores nuclear fuel outside Government custody,
4. erects, operates or otherwise holds an installation for the production or fission of nuclear fuel, or for the reprocessing of irradiated nuclear fuel, or materially alters the installation or its operation,
5. treats, processes or otherwise uses nuclear fuel outside an installation for the production or fission of nuclear fuel, or for the reprocessing of irradiated nuclear fuel, or any person who deviates to an considerable extent from the procedure laid down in a licence issued under sub-section (1) of section 9 for treatment, processing or other use, or who materially

alters the installation or its location as specified in the licence,

shall be liable to imprisonment and a fine not exceeding DM 100,000.–, or to one or the other of these penalties.

(2) The same penalties shall be incurred by any person who wilfully –

1. fails to surrender nuclear fuel without delay, in contravention of sub-sections (3) and (4) of section 5;
2. issues nuclear fuel to unauthorized persons, in contravention of sub-section (5) of section 5;
3. contravenes any provision of an ordinance made under sections 11 and 12, where such ordinance refers to this penal provision.

(3) Any person who, by an act of the kind specified in sub-section (1) or (2), knowingly endangers the life or health of another person, or property of considerable value belonging to another person, such danger originating from nuclear fission or ionizing radiation, shall be liable to imprisonment for a term of not less than three months. In addition, a fine not exceeding DM 100,000.– may be imposed.

(4) Any person who, through negligence, commits one of the acts specified in sub-sections (1) and (2), shall be liable to imprisonment for a term not exceeding two years and a fine not exceeding DM 100,000.–, or to one or the other of these penalties.

SECTION 46
STATUTORY OFFENCES

(1) Any person who, wilfully or negligently, contravenes the determination under subsection (1) of section 13, conditions imposed under sub-section (1) of section 17, or immediately enforceable orders issued by the Government supervisory authority under sub-section (3) of section 19, shall be guilty of a statutory offence.

(2) A person shall also be guilty of a statutory offence, if he wilfully or negligently –

1. contravenes any provision of an ordinance made under section 11 or 12;
2. contravenes any immediately enforceable direction, issued by the supervisory authority under an ordinance made in pursuance of paragraph 9 of sub-section (1) of section 12,

where such ordinance refers to this provision on fines.

(3) Where statutory offences under sub-section (1) or (2) have been committed wilfully, they may render the offender liable to a fine not exceeding DM 100,000.–. Where such offences have been committed negligently, the offender may render himself liable to a fine not exceeding DM 50,000.–.

(4) It shall furthermore be deemed to be a statutory offence if, in the course of carriage, a person wilfully or negligently fails to carry the licence required under section 4 or under an ordinance made in pursuance of section 11 or 12. Such offence may render the offender liable to a fine not exceeding DM 1,000.–.

(5) Where the import or export of radioactive substances requires a licence, by virtue of an ordinance made under section 11, the Federal Office for Trade and Industry shall be competent to prosecute, and impose penalties in respect of statutory offences committed by failure to comply with such requirement, or by violation of any condition imposed by the Federal Office in respect of such licence. The Federal Office shall also decide on the modification and revocation of any fine which has become absolute and has not been under judicial review (sub-section (2) of section 66 of the Law on Statutory Offences [Gesetz über Ordnungswidrigkeiten]).

SECTION 47
PUNISHABLE VIOLATION OF SAFETY REGULATIONS, CONDITIONS AND ORDERS

Any person who, by a wilful act as specified in sub-section (1) or (2) of section 46, wilfully or negligently endangers the life or health of another person, or property of considerable value belonging to another person, through nuclear fission or ionizing radiation, shall be liable to imprisonment and a fine not exceeding DM 100,000.–, or to either of these penalties. Where the offender causes the danger knowingly, the penalty shall be imprisonment for a term of not less than three months; in addition, a fine not exceeding DM 100,000.– may be imposed.

SECTION 48
VIOLATION OF OBLIGATIONS CONCERNING PRODUCTION AND SUPPLY

(1) Any person who, knowingly produces or supplies defective installations for the production or fission of nuclear fuel, or for the reprocessing of irradiated nuclear fuel, or who produces or supplies defective objects intended for the erection or operation of such installation, and thereby knowingly endangers the life or health of another person, or property of considerable value belonging to another person, such danger being connected with the effects of a nuclear fission process or radiation from a radioactive substance, shall be liable to imprisonment for a term of not less than six months.

(2) The attempt shall be punishable.

(3) In particularly grave cases the penalty shall be penal servitude for a term of not more than ten years.

(4) Any person who, not knowingly, but wilfully or negligently, causes danger in the cases specified in sub-section (1), shall be liable to imprisonment.

SECTION 49
CONFISCATION

(1) Objects may be confiscated which have been produced by an act constituting a punishable offence under sections 40 to 42 or which have been used or were intended for the commission of such offence.

(2) Objects may be confiscated which are connected with an offence punishable under sub-sections (1) to (3) of section 45, section 47 or section 48, or which are subject to a fine under the first sentence of sub-section (3) of section 46.

(3) Such objects as are referred to in sub-sections (1) and (2) shall be confiscated, where the protection of the public so requires in view of the nature of the objects, or where it is feared that they might be used for the commission of further punishable offences.

(4) If it be impossible to prosecute or sentence any particular person for such offence, confiscation shall or may be ordered, notwithstanding this fact, provided that the conditions are otherwise present under which confiscation may be ordered or permitted. The same shall apply where the Court imposes no penalty.

(5) Where no fine may be imposed for a statutory offence of the kind specified in the first sentence of sub-section (3) of section 46, the first sentence of sub-section (4) shall apply correspondingly.

SECTION 50
REPARATION

(1) If, at the time when the Court's decision or the imposition of a fine became absolute, the confiscated objects were the property neither of the offender nor of an accessory, or if they were encumbered with the right of a third person, the person entitled shall be paid appropriate reparation.

(2) There shall be no obligation to pay reparation –

1. if the person entitled has, at least carelessly, contributed to the object or right becoming an instrument or object of the offence, or of its preparation, or of any other act connected therewith, which renders the offender liable to imprisonment or to a fine;
2. if the person entitled has derived improper benefit from the act; or
3. if the person entitled, knowing the circumstances which may lead to confiscation, has improperly acquired the object.

SECTION 51
RELATION TO OTHER PENAL PROVISIONS

(1) Offences under section 40, sub-section (2) of section 41, and section 42, are crimes constituting a public danger, within the meaning of section 138 of the Penal Code (Strafgesetzbuch).

(2) They shall be deemed equivalent to the crimes involving the use of explosives within the meaning of paragraph 3 of sub-section (3) of section 4 of the Penal Code.

(3) Where an act is punishable under the provisions of this Act only, or in conjunction with the provisions of the Penal Code, sections 5 to 13 of the Act on the Criminal Use of Explosives Constituting a Public Hazard (Gesetz gegen den verbrecherischen und gemeingefährlichen Gebrauch von Sprengstoffen) of June 9, 1884 (Reichsgesetzblatt, p. 61) shall not apply.

(4) Crimes under section 40 or sub-section (2) of section 41 shall be under the jurisdiction of the Courts of Assizes (Schwurgerichte) (sections 79 and 80 of the Judicature Act [Gerichtsverfassungsgesetz]).

SECTION 52
DISCLOSURE OF SECRETS

(1) Any person who, without authority, discloses a business or technical secret, or a secret confided or known to a medical practitioner or dental surgeon or person working under him, in their respective capacities, which has come to his knowledge as a member of an authority entrusted with the execution of this Act or as an officially appointed expert during his work in connection with this Act, shall be liable to imprisonment for a term not exceeding two years, or to a fine. Legal proceedings shall be taken only at the request of the injured person.

(2) Any person who misuses a secret of the nature specified in sub-section (1), which has come to his knowledge under the circumstances referred to therein, in order to procure pecuniary benefit for himself or for another person, or to cause injury to another person, shall be liable to imprisonment. In addition, a fine may be imposed.

PART VI
FINAL PROVISIONS

SECTION 53
REGISTRATION OF DAMAGE DUE TO UNKNOWN CAUSES

Damage which, in the light of existing scientific knowledge, has been caused by the effects of radiation from radioactive substances but cannot be traced to any particular person, shall be registered with and investigated by the Federal Minister of Nuclear Energy and Water Economy.

SECTION 54
ISSUE OF STATUTORY ORDINANCES

(1) Statutory ordinances under sections 11, 12, 13 and sub-section (5) of section 21, shall be issued by the Federal Government. The same shall apply to statutory ordinances issued under section 10, in so far as exemption is granted from the requirement of a licence under section 7. All other statutory ordinances for which this Act provides shall be issued by the Federal Minister of Nuclear Energy and Water Economy.

(2) The statutory ordinances require the consent of the Bundesrat. This shall not apply to statutory ordinances which merely stipulate physical, technical and radiation biology standards, in place of those laid down in statutory ordinances pursuant to sections 11 and 12.

(3) The Federal Government may by statutory ordinance delegate the enabling powers specified in sections 11 and 12, wholly or in part, to the Federal Minister of Nuclear Energy and Water Economy.

SECTION 55
REPEAL OF LEGAL PROVISIONS

(1) The following legal provisions shall cease to have effect: –

1. sub-paragraphs (a) and (b) of paragraph 1 of Article 1 of Law No. 22 of the Allied High Commission of March 2, 1950, concerning the Control of Materials, Facilities and Equipment Relating to Atomic Energy (Official Gazette of the Allied High Commission for Germany, p. 122), as amended by the Laws of the Allied High Commission for Germany No. 53 of April 26, 1951 (Official Gazette of the Allied High Commission for Germany, pp. 882 and 990) and No. 68 of December 14, 1951 (Official Gazette of the Allied High Commission for Germany, p. 1361);
2. the Bavarian Act on the Provisional Regulation of the Erection and Operation of Nuclear Reactors and of the Use of Radioactive Isotopes of July 13, 1957 (Bayerisches Gesetz- und Verordnungsblatt, p. 147) as amended by the Act of November 12, 1958 (Bayerisches Gesetz- und Verordnungsblatt, p. 330);
3. the Hessian Act on the Provisional Regulation of the Erection and Operation of Nuclear Research Reactors and on Radiation Protection of October 1, 1957 (Gesetz- und Verordnungsblatt für das Land Hessen, p. 141) as amended by the Act of April 30, 1959 (Gesetz- und Verordnungsblatt für das Land Hessen, p. 9);
4. the Hamburg Act on the Provisional Regulation of the Use of Nuclear Energy of October 18, 1957 (Hamburgisches Gesetz- und Verordnungsblatt, p. 465);
5. the Land North Rhine-Westphalia Act on the Provisional Regulation of the Erection and Operation of Nuclear Installations of February 4, 1958 (Gesetz- und Verordnungsblatt für das Land Nordrhein-Westfalen, p. 39);
6. the Land Baden-Württemberg Act on the Provisional Regulation of the Use of Nuclear Energy of May 12, 1958 (Gesetzblatt für Baden-Württemberg, p. 129);
7. the Berlin Act on the Regulation of the Scientific Use of Nuclear Energy (Atomic Energy Act) of June 26, 1958

Gesetz- und Verordnungsblatt für Berlin, p. 563); this does not apply to section 8, in so far as contraventions under section 40 of the First Ordinance under the Atomic Energy Act (Radiation Protection Ordinance) of October 22, 1958 (Gesetz- und Verordnungsblatt für Berlin, p. 1029) are concerned;

8. the Land Schleswig-Holstein Act on the Erection and Operation of Nuclear Research Reactors and for the Regulation of Radiation Protection of June 30, 1958 Gesetz- undVerordnungsblatt für Schleswig-Holstein, p. 225); this does not apply to sections 11 to 13, in so far as contraventions under sections 47 and 48 of the (Police) Ordinance on the Protection against Radiation Hazards (Gesetz- und Verordnungsblatt für Schleswig-Holstein, p. 229) are concerned.

(2) On the coming into force of the first statutory ordinance made under sections 11 and 12, the following provisions shall cease to have effect: –

1. sub-section (4) of section 4 and sub-section (2) of section 5 of the Roentgen-Ordinance of February 7, 1941 (Reichsgesetzblatt I, p. 68) as amended by the Ordinance of January 17, 1942 (Reichsgesetzblatt I, p. 31);
2. such provisions of Law No. 22 of the Allied High Commission as are not superseded by paragraph 1 of sub-section (1) of this section, and bye-law No. 1 to Law No. 22 of April 28, 1951 (Official Gazette of the Allied High Commission for Germany, p. 883);
3. section 8 of the Berlin Act of June 26, 1958, in so far as this provision ist not superseded by paragraph 7 of sub-section (1);
4. sections 11 to 13 of the Schleswig-Holstein Act of June 30, 1958, in so far as these provisions are not superseded by paragraph 8 of sub-section (1);
5. the Bavarian First Ordinance on the Protection of the General Public against Radiation Hazards (First Atomic Energy Ordinance) of August 29, 1957 (Bayerisches Gesetz- und Verordnungsblatt, p. 185
6. the Schleswig-Holstein (Police) Ordinance on the Protection against Radiation Hazards (Radiaiton Protection Ordinance) of July 17, 1958 (Gesetz- und Verordnungsblatt für Schleswig-Holstein, p. 229);
7. the Berlin First Ordinance under the Atomic Energy Act (Radiation Protection Ordinance) of Octobre 22, 1958 (Gesetz- und Verordnungsblatt für Berlin, p. 1029).

(3) Paragraph 10 of sub-section (3) of section 24 of the Trading and Industrial Code, as amended by the Act of September 29, 1953 (Bundesgesetzblatt 1, p. 1459) shall be deleted.

SECTION 56

LICENCES ISSUED UNDER LAND LEGISLATION

(1) Any licenses, exemptions or approvals granted under Land legislation for the erection and operation of installations within the meaning of section 7, shall continue to have effect. They shall be deemed equivalent to licences granted under section 7, and the conditions attaching to them shall be equivalent to such conditions as are imposed under sub-section (1) of section 17. In so far as a licence issued under Land legislation includes stipulations for the provision to be made by the operator of the installation in regard of financial security to cover legal liability to pay compensation for damage, such stipulations shall, subject to the provisions of sub-section (2) be considered a determination within the meaning of sub-section (1) of section 13.

(2) Within three months after the coming into force of this Act, the public authority (sub-section (2) of section 24) shall determine the amount which the operator of the installation must provide as financial security. The latter half of the second sentence of sub-section (1) of sec-

tion 13 shall apply correspondingly. Where a liability has been established in pursuance of sub-section (4) of section 13, such liability shall be retroactive as from the date of the coming into force of this Act.

SECTION 57
EXCLUSION OF CERTAIN LEGAL PROVISIONS

Sections 1 to 4 of the Act on the Criminal Use of Explosives Constituting a Public Hazard of June 9, 1884 (Reichsgesetzblatt, p. 61), as amended by the Ordinance of August 8, 1941 (Reichsgesetzblatt I, p. 531), and such legal provisions as are made under the said Act, as well as legal provisions of the Laender concerning explosives, shall not apply to any handling of nuclear fuel.

SECTION 58
VALIDITY IN BERLIN

In accordance with sub-section (1) of section 13 of the Third Transition Act (Drittes Überleitungsgesetz) of January 4, 1952 (Bundesgesetzblatt I, p. 1), this Act shall also be valid in the Land Berlin. Statutory ordinances made under this Act shall apply to the Land Berlin in accordance with section 14 of the Third Transition Act.

SECTION 59
COMING INTO FORCE

This Act shall come into force on the day following its promulgation; sections 40 to 52 shall not come into force in the Land Berlin, however, until the day after promulgation of the Application Act (Übernahmegesetz) in the Gesetz- und Verordnungsblatt für Berlin.

The foregoing Act is hereby promulgated.
Bonn, December 23, 1959
The Federal President
Lübke
The Federal Chancellor
Adenauer
The Federal Minister of
Nuclear Energy and Water Economy
Balke

FIRST ACT TO AMEND AND SUPPLEMENT THE ATOMIC ENERGY ACT

April 23, 1963
(Bundesgesetzbl. 1963 I, p. 201)

The following Act has been enacted by the Bundestag, with the consent of the Bundesrat.

SECTION 1

The Atomic Energy Act of December 23, 1959 (Bundesgesetzblatt I, p. 814), shall be amended and supplemented to read as follows:

1. Section 4 shall be amended to read as follows:
    - a) The second and third sentence of sub-section (1) shall be deleted.
    - b) In paragraph 1 of sub-section (2) the words "and that the consignment is accompanied by a person authorized to give instructions, with such expert knowledge as is required for the carriage of nuclear fuel" shall be deleted.
    - c) Sub-sections (3) and (4) shall be amended to read as follows:

      "(3) The licence shall be granted separately for each carriage; in general, such licence will be granted for a period not exceeding three years, provided that this is in conformity with the purposes as specified in paragraphs 1 to 4 of section 1.

      (4) A duplicate or certified copy of the licence shall be available during the carriage and shall be produced to the competent authority or its duly authorized agents on request. This shall not apply if the carriage by rail is effected by an operator of a railway."
    - d) The former sub-section (4) shall become sub-section (5).
2. Section 7 shall be amended and supplemented to read as follows:
    - a) In sub-section (1) the word "stationary" shall be inserted before the word "installation".
    - b) The following new sub-section (4) shall be inserted after sub-section (3):

      "(4) Sub-sections (1) to (3) shall apply correspondingly to the non-stationary installations. However, the statutory ordinance as specified in the third sentence of sub-section (3) may provide that public announcement of the project and the availability for public inspection of the records may be dispensed with, and that in so far objections shall not be examined orally."
    - c) The former sub-section (4) shall become sub-section (5).
3. Section 10 shall be amended to read as follows:

   "Section 10.

   Exemptions from the provisions of sections 3 to 7 and 9 may be granted by statutory ordinance, provided that only such quantities or kinds of nuclear fuel or certain protective measures or equipment are involved, which are not likely to cause damage due to a self-sustaining chain reaction or to the effects of ionizing radiation and as far as this is in conformity with the purposes as specified in paragraphs 3 and 4 of section 1."
4. The second sentence of sub-section (1) of section 24 shall be amended to read as follows:

   "Control of any carriage of nuclear fuel and of other radioactive substances by rail and by sea which is effected by the German Federal Railways (Deutsche Bundesbahn) shall, however, be exercised by such bodies of the German Federal Railways as have been designated by the Federal Minister of Transport (Bundesminister für Verkehr)"

5. The first sentence of sub-section (4) of section 46 shall be amended to read as follows:
   "It shall furthermore be deemed to be a statutory offence if, in the course of the carriage, a person wilfully or negligently fails to carry the proof of the licence required under section 4 or under a statutory ordinance made in pursuance of section 11 or 12."

SECTION 2

In accordance with sub-section (1) of section 13 of the Third Transition Act (Drittes Überleitungsgesetz) of January 4, 1952 (Bundesgesetzbl. I, p. 1), this Act shall also be valid in the Land Berlin.

SECTION 3

This Act shall come into force on the day following its promulgation.

The foregoing Act is hereby promulgated
Bonn, April 23, 1963
The Federal President
Lübke
For the Federal Chancellor
The Federal Minister of Labour
and Social Affairs
Blank
The Federal Minister for Scientific Research
Lenz

VIII ATOMIC ENERGY PROGRAMME 1963–1967 FEDERAL REPUBLIC OF GERMANY

PREFACE

In July 1962, my predecessor in office, Prof. Dr.-Ing. Siegfried Balke, had asked the German Atomic Energy Advisory Committee to draft a long-term programme designed to promote the exploration and application of nuclear energy in the Federal Republic of Germany. The German Atomic Energy Advisory Committee, formes to advise the Federal Ministry for Scientific Research on all matters of importance in the nuclear energy field, responded to the suggestion of its Chairman and instructed the Chair to set up a special committee for this purpose. The Chair, which comprises the Chairman and three vice-Chairmen, namely Prof. Otto Hahn representing science, Prof. Karl Winnacker representing industry, and State Secretary Prof. Leo Brandt representing the administration, concluded that the best approach would be to call upon the direct co-operation by the working groups of the "Research and Training," "Technical and Economic Problems regarding Reactors" and "Radiation Protection" expert committees–which are fully conversant with the issues concerning research and development–to participate in drawing up such a programme.

To this end the chairman and vice-chairman of ten working groups into which the three expert committees are subdivided appointed an ad-hoc committee to discuss in detail whether or not projects suggested by the working groups were to be included in the programme of promotion. In that manner it was possible for the working groups to elaborate on technical questions, while the broader aspects were taken up at a higher level by the committee of chairmen and vice-chairmen. The executive secretariat of the German Atomic Energy Advisory Committee was responsible for the mechanics of this multifarious cooperation. It made the necessary arrangements to ensure speedy communication to all concerned of important results of the discussions, and to keep them fully informed on the numerous suggestions made by individuals or groups.

This panel of experts, designated "German Atomic Energy Programme No. I," took up its advisory activities on October 31 1962, under the chairmanship of State Secretary Prof. Brandt. Following detailed discussions, ten advisory members of the panel were asked to submit a first draft of the atomic energy programme by February 1 1963. These ten experts constituted the sub-committee "German Atomic Energy Programme No. II" under the chairmanship of Prof. Heinz Maier-Leibnitz. They compiled the raw material furnished by the working groups for the first draft, and laid down the framework for the programme on January 7 1963. The first draft was worded in a closed meeting held from January 21–25 1963. On February 1 1963, this draft was discussed by the committee "German Atomic Energy Programme No. I". Subsequently, all participants were again invited to suggest any changes or amendments. From March 11–15 1963, Prof. Maier-Leibnitz and his deputy, Dr. Boettcher, with the assistance of two members of my Ministry, reviewed the proposals received, and thereupon prepared a second version of the programme. Except for some minor amendments, this draft was approved by the German Atomic Energy Advisory Committee at its session on May 4 1963.

I am quite aware that I have described the coming into being of this programme in more detail than is usual. Parliament and the public may gather therefrom the amount of work and individual effort associated with the preparation of a programme of this kind. I consider it my duty to acknowledge publically the excellent work rendered by all honorary advisers of the German Atomic Energy Advisory Committee, mentioning Prof. Maier-Leibnitz and Dr. Boettcher as representing all other members. The finest recognition these men could meet with in compensation of their devoted and pioneering activity would be a speedy and comprehensive implementation of the suggestions put forward in this programme. These suggestions are moderate and in keeping with the resources and potential available in Germany with regard to the exploration and utilization of nuclear energy for peaceful purposes. The suggestions are to be considered as mere recommendations. Federal Government, Bundestag, and Bundesrat, therefore, are not bound in any way–neither legally nor actually–to follow these recommendations in whole or in part. However, these bodies are obligated to discuss the suggestions very thoroughly, and would be well advised to adopt them to an extent which the general budgetary situation of Bund and Laender will permit during the next few years, except where scientific and technical advances necessitate modifications or amendments to the programme.

The German Atomic Energy Programme which runs from 1963 until 1967 in conformity with the five-year period covered by the Second Research Programme of the European Atomic Energy Community (Euratom), does not constitute a rigid plan but rather a yardstick for determining the most expedient measures of promotion and planning to be taken by governmental authorities or on private initiative. Such measures may have to be periodically improved and adapted to keep pace with the rapid progress in this expanding field. The authors of the programme have intentionally confined themselves to stating the amount of public funds required to carry this programme into effect. They did not consider the expenditures to be incurred by private industry on such ventures, and they trust in the readiness on the part of free enterprise to develop its own initiative, assume responsibility and accept certain risks. As far as public expenditure is concerned, the authors count on support by both Parliament and Government.

In the years since 1955, research in the nuclear energy field was readily promoted in the Federal Republic. This formed the prerequisite for the Federal Republic to render, in the not too distant future, the contribution expected of it on the international scene. In addition, efficient groups were established by industry as a basis for participating in the activities of a newly-emerging market. However, despite the remarkable development in this country, the fact must not be overlooked that other countries, where work of this type was started earlier and promoted on a much larger scale, were generally able to maintain and even increase their lead in this regard.

Now that the results achieved during the past years place the Federal Republic in a position to enter into a phase of industrial application of some of the noticeable concepts developed, a concentration and coordination of pertinent efforts, and intensified promotive action by the Government, would appear necessary. The promotion of research activities requires further expansion along similar lines as were employed in the past, until the scope aimed at is reached. But a new approach will have to be taken with regard to industrial developments and the construction of large experimental plants in order to ensure, by concerted action between Government and industry, that the technical potential of the Federal Republic is exploited to an extent justifying the considerable public interest in developing this field. In this context, experience by other countries has to be considered whereby the initiative of a free market economy alone is not sufficient. Rather, the objective of utilizing the possibilities inherent in nuclear energy, with its diversified projections into other branches, can–in the light of the magnitude of the tasks ahead–be achieved only by pooling an active and systematic promotion by the Government with the industry's own initiative.

The atomic energy programme as submitted sets the framework of the nature and extent of promoting both research in the natural sciences and developments of the industry during the forthcoming five-year period from 1963–1967. It is meant to be a yardstick for appraisal and selection of research and development projects. Great importance will be attached to a thorough review and effective coordination reflecting the objectives set forth in the programme, in particular as far as development projects and related work are concerned. An attempt has been made to incorporate therein, beforehand, developmental trends as they present themselves today. However, on account of the rapid progress which technical advancements are making, the programme will require periodic review and adjustment to changed situations.

The scope of the programme is confined to natural science and technical aspects. A supplement of studies to cover also the economic, financial and legal outlook is considered essential. Moreover, it is recommended that the social economic issues raised in connection with the atomic energy programme be analysed as well.

I. GENERAL ASPECTS

A. OBJECTIVES OF PROMOTION

The Ministry for Scientific Research is to promote work in the following areas of the nuclear energy field:

1. EXPLORATION OF NUCLEAR ENERGY

This area comprises adequate basic research, applied research, and technical development including radiation protection; the entire range of industrial tasks leading up to the construction and testing of reactors; starting and expanding related supply industries; ensuring the availability of the raw materials required; and finally some borderline activities such as the manufacture and application of radiation sources, accelerators and radioisotopes.

2. APPLICATION OF NUCLEAR RADIATION AND RADIOISOTOPES IN OTHER BRANCHES OF SCIENCE AND ENGINEERING

The use of nuclear radiation opens new horizons for numerous domains of science and engineering. Introducing and advancing new techniques of this kind is a task of general importance, and is expected in some instances–such as the fields of biology and medicine–to yield results of great significance to the practical development of nuclear energy.

In those cases promotion by the Ministry for Scientific Research should be understood to be merely complementary to promotion action by other competent bodies.

3. STIMULUS TO OTHER FIELDS

Promotion measures in specific areas are known to advance science and technical progress in general. This consideration represents an important incentive for the promotion of nuclear energy by the Ministry for Scientific Research. Though this motive generally does not offer any reason for promoting specific tasks, it lends itself to assessing the overall scope of promotion considered desirable.

B. STATUS AND POTENTIAL AS BASIS OF THE PROGRAMME

For a decision on the nature and extent of promotion measures to be launched in various fields, the present status of development in the Federal Republic as a whole, and the availability of materials and labour as prerequisites for the performance of specific research and development tasks, have to be taken into consideration.

If the manner in which the research activities have developed in Germany is compared with that of other countries of similar size, it becomes evident that, after falling behind owing to historical events, the Federal Republic has not made sufficient achievements to date to allow the country to catch up again. The vigorous promotion of nuclear energy in other countries is largely attributable to the fact that a military interest exists there at the same time, and that accordingly all efforts are directed and sponsored rather rigidly. However, the statement applies also if only the efforts devoted to the peaceful applications of nuclear energy are considered. Developments in Germany no doubt were handicapped also by the fact that in the first post-war decades private industry was faced with the task of filling a large backlog in other areas of activity. Moreover, the opinion put forward in the past that any technical evaluation in this field should originate primarily from the free initiative of industry was found to be inapplicable. In the absence of a market or a directly-foreseeable commercial application, industry was unable to raise from own resources the heavy funds required for financing the activities in the nuclear field. In particular, neither the reactor engineering firms nor the manufacturers of nuclear fuel in Germany are in a position to carry the large technical risks associated with the construction of such novel plants. Without Government support the nuclear industry in the Federal Republic will not be able to become competitive, all the more so since during the same period the industries in other countries have gone through a phase of rapid technical expansion financed almost entirely by subsidies from their Governments.

The facilities and expert labour available in both the scientific and technical sphere are a natural limitation of what can be achieved in the immediate future. If an intensive promotion of this potential is continued, universities and special scientific institutes appear to afford an appropriate basis for extended research efforts. This is true especially since several major, up-to-date research establishments–in particular nuclear research centres–are presently under construction and may be expected to reach a sizeable standard during the next few years. Likewise, professional training facilities for technical personnel will require substantial extension.

Not so bright are the prospects with regard to the industrial potential, whose growth depends on the materialization of technical projects. Promotion measures needed in the future will have to take this fact into account.

C. LEVELS AND BODIES INSTRUMENTAL IN PROMOTING RESEARCH AND DEVELOPMENT

1. BASIC RESEARCH

a) SPECIFIC PROMOTION OF BASIC RESEARCH

Basic research aims at gaining new insights into the field concerned, although nature and the extent of effort cannot be forecast when a study is initiated. Consequently, in the field of basic research it is impracticable to set up a programme which aims at clearly defined results. Nevertheless, it is possible all the same as part of the promotion of nuclear energy to select certain sectors from the overall domain of the sciences whose individual promotion appears to be worthwile for practical application. Action of this kind can well serve to supplement other measures for promoting basic research, such as those by the Deutsche Forschungsgemeinschaft organization.

b) NECESSITY AND SCOPE OF SPECIFIC PROMOTION

The detailed programme in section II below lists several areas eligible for a specific promotion of basic research. Progress made in any of these areas will, in the long run, turn out to be fruitful to the technical field. Leadership in nuclear engineering cannot be imagined without the country also holding a leading position in the domain of fundamental scientific knowledge. For judging the desired scope of our efforts, a comparison with expenditures incurred and results obtained in other countries will provide a valuable standard.

The scientific initiative for which Germany was renowned after World War I, especially in the fields of physics and chemistry, has since passed on largely to other countries. Due to the efforts made in Germany in recent years, attractive employment opportunities again exist in various branches, a new generation of well-trained scientists has been educated, and some of the results of research work performed here have found international recognition. However, a severe backlog is evident in numerous fields. The task ahead now is not only to make up lost ground but also to keep pace with the amplified efforts by other countries in the sphere of basic research.

The amount of basic research which Germany is able to perform finds its natural restriction in the number of scientists and research facilities available, and in the potential which a steady increase of that number would create. In the light of the fact that amplified basic research is a definite must, the possibilities at hand should be fully exploited rather than restricted by inadequate financial support.

c) COMPETENT BODIES

Basic research is taken care of, to a varying degree, by the universities, Max-Planck institutes, research centres, research establishments operated by Bund and Laender, industrial institutes and, within the framework of international cooperation, primarily by the joint research establishments of Euratom.

Basic research at the universities is in line with Humboldt's principle postulating the unity of research and academic instruction, in that the results of research tasks directly benefit the training of young scientists. More effective coordination of the efforts by individual institutes will also permit the conducting of major research schemes at university level.

The various Max-Planck institutes offer the possibility that specific and extensive research projects can be handled there without the burden of lecturing commitments. The development during the past few years almost invariably indicates a trend towards linking up more closely with the work performed at the universities; this, in turn, has caused the Max-Planck institutes to participate in university training.

The general objectives pursued by research centres and public research establishments frequently place the focus of activities on applied research and development. This provides the opportunity to pool and utilize for basic research work large-scale facilities which single universities would not be in a position to operate. In addition, every research centre has to devote part of its activities to basic research in order to be able to perform efficiently the tasks placed before it by the problems of practical application.

As far as industry is concerned, basic research is generally limited to the amount required for supporting industry's own development efforts. Wherever possible it will be prudent to resort to research at universities and other levels of education. This approach is justified by the fact that the results of basic research should be available to all users alike. It constitutes a mandate on other competent bodies to intensify their basic research.

Basic research work is also performed to a limited degree by the joint research establishments of Euratom. This serves to raise the potential of the member countries in the branches concerned. An amplification of basic research efforts by Euratom would be extremely useful.

d) HARMONIZATION

Basic research does not lend itself very well to steering. Even duplication of work may in some instances prove to be of advantage. However, of decisive importance is the reciprocal knowledge and harmonization of research projects. In this context, the practice of having relevant applications reviewed by the competent working groups of the German Atomic Energy Advisory Committee has yielded very good results. On the international scene, the participation in conferences, exchange of scientists, and cooperation between institutes have been sponsored successfully. Particular possibilities are afforded by scientific cooperation within the framework of Euratom, because in that manner the foundations of research work can be significantly expanded.

2. APPLIED RESEARCH

In applied research, the results of basic research are examined to determine their applicability to practical problems, and to ascertain the methods by which this can be achieved. By the very nature of things, applied research cannot be strictly separated from basic research nor from technical development. It would seem quite desirable that aspects of practical application be considered also in basic research studies. Therefore an increased activity in applied research is certain to be welcomed and also supported by the universities. The bulk of such applied research will be conducted by the research centres, with the joint research establishments of Euratom playing a special role, because the knowledge gained there will be disseminated direct to all member countries of the Community. It stands to reason that in industry applied research is linked up more closely with the technical development. The German Atomic Energy Programme contains no seperate section devoted to applied research which has been dealt with partly under basic research and, to a larger part, under the section on technical development.

It need not be emphasized that the object of the efforts and the association with nuclear energy can be recognized more clearly in applied research than in basic research. Consequently, more thorough planning is practicable and expedient. Coordination of work performed at different places is an important aspect in the promotion of research and should also be borne in mind by participating research centres and institutes. Some of the wide range of equipment available at the research centres could well be made use of in connection with development problems which arise in the industry.

3. DEVELOPMENT

The object of any technical development is to calculate the multitude of details required for adopting a technical process on an industrial scale or for introducing a product in a manufacturing plant. In those cases, the aspects brought out by applied research are joined by considerations such as operational safety and economics, either of which can have a great bearing in the industrial sector. Development work in this sense has proved to be an

Indispensable prerequisite for almost every industrial application, because it is not focussed on fundamental scientific knowledge but primarily on producing the practical experience on which any successful adoption of an industrial process is absolutely reliant.

It is therefore prudent that projects of this kind are promoted, particulary by the industrial firms engaged on them. In view of the high cost which such projects usually involve, coordination of such development work must be imperative. Processes intended to serve the same technical purpose can be sponsored simultaneously at various locations, thereby permitting final selection of the best results. Large-scale technical development programmes should be launched, or continued only if a concrete interest exists, under a major project in progress or proposed, for such work to be performed. Here again, achievements made by other countries and on the international scene require full attention, although observation alone will in many instances not reduce our own developmental efforts, since practical experience and training of company personnel frequently are extremely valuable assets for a contemplated industrial application. Close cooperation by all organizations engaged on work of a similar nature will be prolific in most cases. But it can result in complete success only if the efforts of all participants are comparable.

Where problems require extremely heavy expenditure, pooling of development work on a supranational level may be a worthwhile approach, as proposed in the case of the Euratom Transuranium Institute.

Industrial progress will depend largely on the profoundness and completeness of technical developments. It would appear that this viewpoint has not been fully appreciated in many instances. Development projects too expensive for financing solely by industry should be made feasible by the allocation of more public funds. Such promotion will also be a help in ensuring that substantial portions of the results of such developments are made available to similar developments by other firms, without any violation of the rights which originate from own work performed by the developing firms.

4. TECHNICAL REALIZATION

In the narrower field of reactor engineering and the setting-up of suitable manufacturing plants for a supply industry, experience of past years indicates that a start based solely on the initiative of private industry is faced with extreme obstacles, mainly from two reasons: firstly, the development of nuclear plant involves heavy expenditures frequently in amounts as high as the subsequent construction cost of the plant concerned. Such expenditures exceed the financial capacity of both constructor and purchaser of the first plant; secondly, in the case of initial construction of a reactor type already proven elsewhere, the reactor engineering firm will not be in a position to offer extensive guarantees to an interested customer, since tests carried out on a comparatively small scale cannot furnish the statistical experience required for such an undertaking. It can be accumulated only from several years operation of the plants concerned; this means that in the absence of such operating experience the purchaser of the plant runs an exceptionally great risk, particularly since investments in this field are very substantial. This is true all the more for reactor types which operate on new principles or which represent advanced versions of reactor types already proven in other countries. A similar situation prevails in regard to major plants of a supply industry, or in the case of specific ancillary installations such as for reprocessing spent nuclear fuel, disposal or permanent storage of radioactive waste, and so on. In some instances it has become evident from the developments in other countries that economical operation of such installations can be expected only above a certain minimum size. On the other hand it is reasonable to try to keep the risk associated with first plants within acceptable limits by constructing the plants in the capacity range required to gather the necessary experience for economical size plants.

The consequence of the above reasons–namely high development cost, large risk associated with furnishing guarantees, construction of first plants in uneconomical sizes–is that in the majority of cases the initial reactors put up by the country's industry are unable to produce electric power at competitive prices, even if reactor types proven elsewhere are employed. As a result, utility companies generally are not willing to award contracts for such reactors except where subsidies are granted from public funds for the construction and operation of such prototype plants. The subsidies will have to be the higher, the more novel is the selected reactor concept. Bringing the utility companies into the picture at an early stage is very essential since the experience which the utilities alone can contribute will be invaluable. The past has shown, however, that it is unrealistic to expect of the utility companies alone the initiative for construction and operation of nuclear power plants, as far as reactor "firsts" of German manufacture are concerned. Moreover it would mean overtaxing the utility companies, if in their policy-framing private economy decisions they were to assume a heavy financial burden now while it may take decades before it can be judged whether such decisions are likely to yield profits. That is why at the present time the overall prospects of reactor engineering in Germany are threatened to be governed unduly by present-day economic considerations of the potential customers, to the disadvantage of a development which cannot be dispensed with at long sight. In the light of this situation it is incumbent upon the Government to ensure, by considerably more extensive promotion than so far envisaged, that reactor projects developed by German industrial firms and found fit for construction are in fact materialized complete with the pertinent ancillary installations.

In the case of prototype reactors and ancillary installations, it may become necessary, as in other countries, for the government to bear the entire investment cost of the plants, and that in addition, private industry is called upon to carry only such portion of the operating cost of such plants as it can reasonably be expected to assume.

5. TRAINING OF PERSONNEL

Raising the number of qualified personnel required in connection with nuclear research and the introduction of nuclear energy has in previous years been one of the primary aims of promotion efforts by the Ministry for Scientific Research, and remarkable achievements have in fact been made in this respect. The training of natural scientists and diploma engineers, as well as of nongraduated engineers and auxiliary technical personnel, health physics and reactor technicians was granted promotion. A continuation of these measures is considered to be of great value. In that context, particular importance should be attached to the amplified training of non-graduated engineers–a serious bottleneck troughout the entire engineering field. As in the past, all training programmes should take account of the fact that, with the exception of health physics and reactor technicians, no highly specialized training is needed for the nuclear energy field.

Work in the field of nuclear energy demands scientific and technical personnel with a high standard of general training. Such personnel are afforded the opportunity to acquire the necessary additional knowledge partly by practical experience in the performance of the work, and partly by supplementary professional education. In that manner it is also ensured that the special promotion of training in connection with nuclear energy will not cause any malorientation of vocational guidance.

II. PROGRAMME

The programme, set out below, of promotion measures for the next five years is subdivided into research (basic research, including a part of applied research), development, and construction of nuclear plants. A programme of this kind can attempt only to provide the framework for such promotion and must be open to modification on the basis of more recent knowledge evolved.

A. RESEARCH

As outlined in section I. B, governing criteria for the scope of basic research are the existing number and the accession rate of scientists and research facilities. The success of such research efforts is certainly dependent on the personal initiative of the scientists. The selection of areas to be pursued will be largely influenced by such initiative. Research programmes launched in recent years must be carried on to produce concrete results. Experience has shown that the annual expenditure incurred for setting up facilities such as a research reactor, an accelerator or a research centre, will not exceed the annual expenditure required for utilizing such facilities efficiently.
The sections below indicate various areas in some branches of science where specific promotion would appear desirable. In that context, attention is drawn to a few fields in which particular research efforts should be undertaken.
Applied research is covered by this section to the extent to which it is not performed in direct connection with specific development projects.

1. PHYSICS

Physics and many of it branches are a foundation of nuclear energy. Physical issues also play a role in nuclear chemistry, processes for measuring radiation, and in technical research.

Nuclear Physics as the primary basis of nuclear engineering falls entirely under the basic research eligible for specific promotion. In low-energy nuclear physics and radiation physics, promotion measures initiated previously have created opportunities for the performance of work at the universities, Max Planck Institute, and research centres, and these can be made use of in a profitable manner.

The demand for medium-energy accelerators has been met to a large degree. As part of a further expansion of the research establishments, it is considered that a number of small and medium-capacity accelerators are still needed. In addition, certain replacements and additions will be required for the existing facilities.

There appears to be no demand for general-purpose research reactors during the next few years. However, work requiring high neutron fluxes has aroused considerable interest. In this context, the materialization of the very high flux reactor under discussion by the O.E.C.D. would indeed prove useful.

For investigating the fundamentals of nuclear physics, the main accent rests on high-energy physics. Apart from participation in the CERN Research Centre at Geneva and related studies carried on in Germany, the German DESY project holds a prominent place. On completion of the electron accelerator this project will require further considerable funds to permit extensive utilization of the facilities. Compared with other countries, e. g. France and Great Britain, the German efforts in the high-energy physics field are not very significant. The expansion of groups working in Germany on high-energy physics problems is worthy of promotion, and full utilization of the DESY accelerator, when completed, would be particularly worthwhile. For similar reasons, the construction of a several GeV proton accelerator is currently under discussion.

Also of importance in nuclear physics is the accumulation of nuclear data. Apart from participation in the compilation of an international register of nuclear data, the acquisition of such data has great significance in connection with the planning of fast reactor types. The degree of advancement und perfection of nuclear measuring techniques determines the number of potential applications in different areas, although such applications are developed chiefly throughout the basic studies.

Neutron physics as the basis for determining the operational behaviour of reactors must continue to be fostered by universities and research centres as a branch of training and research. A co-ordination of neutron physics activities with the planning of reactor projects would be prudent.

Fusion and plasma physics research–hoped to be a new source of energy in the not–too–distant future–is at present still at the stage of basic research, and requires heavy expenditure on experimental work. On the other hand, fusion and plasma physics are later expected to stimulate industrial developments in many ways.

In the fields mentioned so far, a continuation of promotion measures at the existing research facilities is felt to be essential, including a general accession rate.

A field in which promotion should be intensified is that of solid-state physics. Not counting partial successes in a few areas, the Federal Republic is generally lagging behind, and the bearing which solid-state physics also has on innumerable issues in the nuclear energy field is continually on the increase. A better understanding of the fundamental principles can do away with the need for a large number of technical tests. From a wealth of applications only a few are listed here: basic knowledge and development of materials, irradiation behaviour of matter, and detection of radiation in solids are some others.

One of the most important tools for both pure solid-state physics and its applications is the work in low-temperature physics for which the Programme recommends additional promotion.

Other branches of physics which may be expected to contribute to the advancement of nuclear energy, and where promotion of special tasks appears justified on that account, are the physics of the atom and of the molecule, the interaction of electromagnetic waves with matter, and thermodynamics. In pertinent applied research, mention must be made of the problem of direct conversion of radiation energy and thermal energy into electric energy. Electronic engineering, which takes its origin from several different sectors of physics, is an outstanding field–in particular the methods for electronic measurement–where nuclear physics acted as a stimulant for other branches. Equally, modern analyzing techniques as an offspring of atomic physics activities deserve special mention.

2. CHEMISTRY

Exploration of the chemical fundamentals in connection with the utilization of nuclear energy is by no means confined to the specific areas of nuclear chemistry, radiochemistry, and radiation chemistry but calls for extensive basic research in numerous branches of chemistry. An area of growing importance, furthermore, is the development of new methods for the application of radionuclides.

In nuclear chemistry and radio-chemistry, basic research comprises, amongst other topics, the determination of nuclear data, methods for separation and analysis, recoil chemistry, the study of high-energy atoms, methods for fabrication of radionuclides and tracer compounds. All of these areas are also the subject of applied research.

Solid-state chemistry serves to investigate structures and basic processes, and thus also constitutes an important element for the technology of materials in the nuclear energy field. In addition, basic research has great importance in metallurgy and metallography.

The separation of materials and radioisotopes, and the fabrication and analysis of nuclear-grade materials, are of extreme significance for any utilization of nuclear energy. In connection with this work, the assessment of nuclear data and the examination of multiple-stage separation processes as well as of catalysts are essential.

Chemical thermodynamics is an area which may contribute valuable information for a range of important branches of this field. Basic research and actual application are closely interwoven here.

For chemical reprocessing of nuclear fuel, the further development of pyrometallurgical methods shows good prospects and deserves promotion, apart from aqueous processes.

In nuclear process engineering a vast number of research subjects and development issues is being worked on.

Continually on the rise is the importance of the application of radioisotopes in various branches of science and engineering (isotope engineering). This comprises the utilization and advancement of tracer techniques, activation analyses, materials testing, fabrication, and quality control, etc.

The use of nuclear energy has imposed novel and in some cases extreme requirements on analytic chemistry whose continued promotion is very urgent. Special importance must be attached to the development of instrumentation for spectrographic, chromatographic, electrochemical, and other methods.

Radiation chemistry is a young field of activity, also on an international level, which would appear to have some significance to the Federal Republic and its highly developed chemical industry. Promotion in this field should, therefore, be concentrated on specified subjects. Some of the most important single areas are: examination of the radicals formed by ionizing radiation, and of the effect of free electrons; of primary processes and radical reactions; of condensation and polymerization reactions as well as enzymic reactions, including the products of such reactions; of the interaction of radiation with natural and artificial macromolecules; furthermore, radiation chemistry of solids and the examination of structural changes caused by application of tracers. In nuclear engineering, the solution of radiation chemistry issues is of particular significance, for example, corrosion problems; coolant behaviour within the reactor system; behaviour of steam vapour in the radiation field; synthesis and transformation of materials by irradiation in a nuclear reactor; in short, the full range of problems of reactor chemistry.

3. ENGINEERING SCIENCES

Technological research is by nature essentially applied research. It deals with problems which arise in connection with nuclear energy and are of more general importance. Technological research is conducted primarily by industrial groups and at the research centres, with the Joint Research Centre of Euratom holding a high rank. Intensified efforts at the universities in this field would be very welcome as it ensures access to these achievements for the rising generation of young engineers. In technological research, co-ordination between the development work of industry and the research centres is expedient, since research results of this kind are often useless in the absence of any links with their practical application. Joint research programmes of industry and research centres would seem to be a desirable proposition.

Moreover, important technological research projects of the industry should be financed by public funds to the extent to which industry is unable to bear the necessary expenditures.

Some major sectors of technological research are as follows:

Engineering Problems relating to Reactor Components

In the development of nuclear reactors, many problems and special requirements arise in areas not previously investigated. Analyzing these problems has general importance over and above specific instances. Examples are: thermal stresses on fuel elements, reactor vessels, and pipe systems; and problems associated with prestressed concrete in reactor plants.

Thermal and Flow Engineering Tests

Some of this work calls for large testing facilities which the industry and research centres have available. Coordination of the activities at these facilities, and finding a connection with development work in progress, are particularly desirable. Basic investigations, using dimensional analysis or other methods suited especially for university institutes, provide valuable supplementary information. This field, for which the designation "reactor thermodynamics" is considered very appropriate, should be dealt with separate from other thermodynamic fields.

Materials Problems

This is a field of eminent importance. A general and specific materials technology has great significance for the development of metallic and non-metallic fuels, canning materials, moderators, reflectors, absorbers, and metallic coolants, and general reactor fuels. Work in this field covers problems on the constitution of metallic and nonmetallic systems; the compatibility of different materials; corrosion problems; irradiation effects on materials properties; manufacture of nuclear-grade metals and alloys; deformation, texture, and recrystallization; technological behaviour; and thermodynamic problems. On the other hand, the general materials technology receives great impetus from the specific requirements which prevail in the nuclear energy field.

Electronic and Control Engineering
The requirements which have to be met in reactor engineering with regard to control and plant safety raise problems of general importance, and their solution will be of use for both the nuclear energy and other technical fields. Therefore the fact that the universities are taking up this branch of science is gratifying.

Conduct of Technical Projects
The interrelations between the most divergent technical fields, and the need to plan over long periods in advance, makes it appear justified to have the questions of direction of such projects systematically looked into. It is considered that such an analysis will bring up viewpoints of general interest.

4. RESEARCH ON MINERAL DEPOSITS, OCEANOGRAPHY, METEOROLOGY

Ensuring the availability of raw materials required for the performance of nuclear engineering activities appears to be a necessity. This calls for specific research on mineral deposits in the Federal Republic on a large scale. Research of this type takes its origin from the branches of geoscience and comprises essentially the following:

Investigations regarding the formation of extractable deposit concentrations of uranium, thorium, bismuth, lithium, beryllium, barium, and others in the geochemical cycle, neutron activation analysis for the exploration of mineral deposits and geochemical prospecting, isotope geology, and isotope physics. Further important domains include: the use of radioisotopes in hydrology, technical geology, soil technology, and mining applications, and the storage of radioactive materials in the ground.

Oceanography: Migration of radioactive waste in the seas; use of radioisotopes to study the intermingling of substances in the sea, to investigate flow phenomena, movement of sediments, etc.; exchange processes in boundary layers, origin of water courses, and so on.

Meteorology: Problems relating to the spreading of natural and artificial radioactivity in the atmosphere; study of large-area circulation and mixing processes in the troposphere, stratosphere, and mesosphere; problems of natural aerosols; water conservation, rainfall, and evaporation problems in the atmosphere; air pollution; climatological questions.

5. MEDICINE, BIOLOGY, AGRICULTURE

Because of the hazards inherent in radiation, biological research is indispensable for nuclear engineering. In addition, radiation biology and the use of radioisotopes offer completely new possibilities for research and practical application in medicine, biology, and agriculture.

Radiobiology: Radiation effects on the overall organism and its structural parts have to be examined for all species of living beings, with the object of inquiring into action mechanisms and acquiring knowledge on all radiation diseases, along with diagnosis and therapy. Significant specialist issues concern relations between the effects of dose rates for different instances of radiation damage and for different types of radiation, in particular for low-level cumulative dose rates, also methods for artificially influencing the radiosensitivity. An area of outstanding importance is the genetic effects of radiation which make extensive and costly test series necessary. In this context, radiation biochemistry is gaining rapid attention. Another area deals with the increased radiosensitivity of organisms during foetal development.

In order to enable an assessment of the exposure of an organism, thorough studies are needed to determine by what channels radionuclides are able to enter and leave the body, and to find means of influencing their excretion. In this field the present status of knowledge is still completely inadequate.

The wealth of experience accumulated in radiation therapy offers a possibility for exploring the effects of radiation on human beings.

Application of Radioactive Materials

The use of radioisotopes in radiation therapy heads the list of all other present-day applications of radioisotopes. Accordingly, investigations designed to improve the methods employed in handling radiation, and to reduce the hazardous nature of radiation, are extremely essential. Metabolism studies of any kind have indeed been revolutionized by the use of radioisotopes. This opens a wide field for future research work. Ionizing radiation is employed for the preservation and sterilization of foodstuffs and other materials. In this respect current interest is concentrated on the question whether any substances harmful to human health are produced in that process. The possibility of changing hereditary features by means of ionizing radiation is frequently adopted in animal and plant breeding today.

Advances in control engineering, and the introduction of modern examination procedures, are expected to exercise a strong bearing on all biological work.

Radiobiological research and development are performed at the universities by institutes of the faculties of natural science, medicine, agriculture, and silviculture; by central laboratories of clinics and hospitals; and by the Max Planck Institute and similar research establishments, etc.

In addition to the above scientific institutes where general biological research is conducted, during the past two decades numerous bodies in the Federal Republic have embarked on the exploration of the effects of high-level radiation of all kinds. In view of the topical importance of the related issues, a separate line designated "radiobiology" has become established. The affinity of radiobiology with all other disciplines of biology, including medicine and agriculture, raises the question as to whether special institutes should be maintained for the performance of research tasks involving high expenditures; however, it is neither practical nor expedient to conduct radiobiological research solely at a few large research centres. One of the reasons why institutes at the universities will benefit from promotion measures in the first place is that the expansion and participation of such institutes in radiobiological research activities provides an opportunity for training the urgently-needed quantity of junior scientists.

B. DEVELOPMENT

1. CONSIDERATIONS MOTIVATING A GERMAN REACTOR DEVELOPMENT PROGRAMME

The development of nuclear reactors in Germany is essential for the following reasons:

a) Judging by the current state of the art, nuclear energy may be expected to be introduced as an additional source of energy for power plants during the forthcoming decade. This necessitates preparatory action now, although the Federal Republic has no energy gap forcing the country to initiate the construction of nuclear power plants at once.

b) A highly industrialized country such as Germany must later on be in a position to offer and construct proven types of nuclear power plants to meet the demand at home and abroad.

c) Technological progress advanced by activities in the nuclear energy field is imperative to maintain the German technical standard in competition and in co-operation with other countries, and in many sectors of industrial manufacture. In this way, promotion of nuclear energy by the Government is apt to constitute a general means of ensuring that the competitive ability of German products is retained.

In past years, German industry was afforded the opportunity to form industrial groups for work in the nuclear field, and to accumulate valuable experience by carrying out preliminary design projects for reactor plants, by own developmental efforts, and partly by the performance of and participation in the construction of small-capacity reactors. Important contributions have been also rendered by detailed design studies and, in a few instances, by reactor construction contracts awarded by the utility companies. Efficient working groups were also set up at the large research centres. These factors are the basis for the performance of a reactor programme today.

Continued organic expansion provided, the capacity of the said groups appears fairly adequate on the whole for carrying out a sizeable and effective Programme. A German reactor programme can of necessity not have the broad scope as that of a large nation such as the United States of America, where an important programme was recently launched sponsoring the use of nuclear energy for peaceful purposes. Some limitations are:

a) the financial expenditure–stated to amount to DM 7 billion in the case of the U.S. programme, with numerous advantages being derived from the existence of a military programme there;

b) the industrial capacity and the extent of a potential market;

c) the large amount of reactor development work performed in other countries on account of which there appears to be no chance of expecting important achievements from Germany unless the efforts are concentrated on a limited number of reactor types.

When the original reactor programme was drafted at Eltville in December 1957, the situation in the reactor engineering field was uncertain. The present-day situation may be outlined as follows: The production of electricity from nuclear energy seems to have become almost economical–at least in areas of high conventional fuel costs and based on large-capacity nuclear power stations. The currently most-perfected and well-proven reactor types are saturated steam producing light-water reactors. Several other reactor types, particularly those operating at higher coolant temperatures, offer promise of similarly successful performance in the future. This has created the prerequisite for the construction of large-scale nuclear power plants. The time has also come in Germany when reactor types considered promising now or in the near future have to be selected, with construction and development of reactors concentrated on the types thus selected. This is referred to as the short-range programme of reactor development.

At the same time interest must be focussed on major development tasks in the more-distant future (long-range programme of reactor development):

The reactor systems developed to date permit the utilization of merely a fraction of the energy sources inserted in the form of uranium or thorium fuel. The known resources of readily-extractable uranium and thorium ore are not very large, which means that by about the end of the present century it will be essential to find methods for the full exploitation of the energy inherent in uranium and thorium which can be achieved by means of fast or thermal breeder reactors now under active development. Likewise the development of reactors with a high conversion ratio is of great importance in this context.

Short-Range Reactor Development Programme

German efforts should aim at reactor types which are considered promising now or in the near future, select them for construction, subsequently construct and bring them to economical operation step by step. This means that of a particular reactor type a range of successive units should be constructed which gradually increase in capacity, are then improved by further development, reach a higher degree of technical perfection and will thereby operate more economically as time progresses.

In cases where an economical reactor type already proven abroad is concerned, such a reactor construction range will demand comparatively little development work, commence with large-capacity units and require only a small amount of promotion by the Government. In contrast, therefore, a construction range based on a new reactor type which does not operate economically consumes a large amount of development expenditure. It must start off with small-capacity prototype reactors, and will not be feasible without considerable public funds.

Selection of the reactor types for any construction range should be governed by the following criteria:

1) The reactor type must show prospects of producing electrical power economically in the near future, and of becoming competitive over a longer period of time. In this context, the possibility of incorporating improvements as a result of foreseeable advancements will have great bearing. For judging the ecomomics, the fuel cycle must be considered under a long-term aspect. In particular, the heavy investments for reprocessing irradiated fuel and the cost of re-using the recovered fissionable material in thermal reactors must be examined.

2) The reactor project must make use of available international experience.

3) It must be ensured that the development and construction of the reactor are performed by an efficient German industrial group. If a project is undertaken in co-operation with a foreign group, it must be ensured that the German group is awarded a substantial share of the work, especially the nuclear portion of the plant to be constructed, and that the German group will continue to participate actively in any further development work.

4) Reactor types which by their novel design promise to be an important German contribution to the development of nuclear reactors, may for this very reason be granted preferential promotion at least during the early stage of development.

For a comparison of the reactor construction ranges which meet the requirements set out under sub-sections (1) to (4) above, the following additional criteria should be observed:

5) Reactor types with good conversion properties should be given preference with a view to improved utilization of the nuclear fuel and to the breeder reactors scheduled for construction later.

6) Reactor types with high coolant temperatures and process steam pressures as employed by modern full-scale power plants should be preferred since they permit the use of novel turbine-generators and have a high fuel utilization because of their increased efficiency.

The reactor construction ranges to be selected are expected to require extensive initial promotion by the Government, at least where reactor types not yet proven are concerned. In particular, the substantial cost of extensive development associated with a successful reactor design can by no means be borne solely by the reactor engineering firms, in the light of the restricted market which will initially exist for such plants. The power utility companies, as the purchasers and operators of such reactors, are expected to ask for compensation for the conceivable operating losses and for the operational risk involved.

As the units constructed within such a range are improved, the financial support by the Government can be gradually reduced, and ultimately discontinued altogether.

The initiative for a development along the lines indicated can be left largely to industry and the power utilities. However, public promotion should be granted only to projects which meet the criteria listed.

Marine Propulsion Reactors

The problem of nuclear-propelled ships is pursued by a number of countries. In the Federal Republic the construction of a "research ship" was decided on with this in mind. Furthermore, several industrial groups are engaged on preliminary designs for marine reactor plants. In the course of the next five years it is planned to proceed with this work; one of the designs for the Hamburg research ship is to be perfected to a level fit for construction, and actual construction initiated.

Long-Range Programme: Breeder Reactors

Under a long-term development directed towards the breeder type of reactor, German contributions in close co-operation with other countries are taking shape. Planning work, basic and developmental tests for the breeder reactor are in progress. Moreover, there are concrete indications of construction ranges on economically attractive thorium converters, and considerations on the development of thorium breeder reactors. Work for the development of breeder reactors calls for exceptionally large amounts of funds and does not make the construction of economical reactor plants look feasible in the immediate future. For that reason projects of this kind cannot at the present time be handled by industry alone; consequently, pertinent development efforts have been made a part of the programme on hand at the research centres. A very agreeable and close co-operation already exists with the United States of America, and concerted action with Euratom (on the basis of association agreements) has been envisaged from the very outset. It is recommended that these activities be continued on an increasing scale. Close co-operation between research centres and industry should, of course, be aimed at from the moment such development work is commenced, in a manner whereby the firms are given an opportunity for responsible participation in working out the projects and are awarded the construction contract. It is considered expedient that the power utility companies be called upon at an early date to join the efforts on advanced breeder projects.

It would seem that the overall programme as outlined above well reflects the capabilities of the industrial groups existing in the Federal Republic and suited for organic expansion.

2. DEVELOPMENT WORK FOR REACTORS

Developing an advanced or new reactor type to a stage fit for actual construction requires considerable financial expenditures which may even approach the cost of construction of the reactor concerned. Such heavy additional expenditures cannot be carried by the developing firm nor by the purchaser of the reactor plant. As in other countries the assumption by the Government of the cost involved is a prerequisite for any development of nuclear reactors in the Federal Republic.

The sections below touch on a number of areas of reactor development. Also dealt with in the respective sections are the measures required prior and subsequent to such development, commencing with the procurement of raw materials to the disposal of wastes. The guiding principle worth noting is that development work should only be promoted in connection with concrete projects.

a) Neutron Physics Design of Nuclear Reactors

The design of a nuclear reactor is based on neutron physics calculations used for optimizing the reactor parameters. Calculations of this type are nowadays performed mainly with the aid of modern electronic computers. Such calculations are supported by subcritical and critical experiments. Also investigated is the dynamic behaviour of the reactor, for which heat transfer phenomena, coolant loops and performance of the turbines to be installed play a role. This step in the development of the reactor has the greatest bearing on the achievable power output and economics of the reactor system.

b) Fuel Cycles

One of the cost-determining factors of nuclear energy is the fuel cycle, not only by the economics of the multitude of related single processes but primarily by the influence which diversified safety requirements exercise on the capital investment.

Provision and Preparation of Raw Materials

Considered over longer periods of time, the size of low-cost uranium and thorium deposits known throughout the world is comparatively limited, and prospecting now in progress will generally have to be continued. In the Federal Republic, work of this kind based on conventional methods has been carried out in recent years with partial success in some cases. For obtaining a true overall picture of the situation it will be necessary to continue and methodically extend such prospecting work in order that not only surface deposits are discovered but also those at depths suitable for mining. The deposits considered worth extracting in the Federal Republic require investigation by exploratory drilling and other pertinent mining operations to determine the quantities, mineral content and the chances for economic extraction.

Equally, the preparation of suitable ores, as already being performed in an existing small-scale industrial plant whose operation should be carried on, is in need of further development within the limits of the conditions prevailing at the individual deposits. Over and above the quantity needed for the fabrication of reactor fuel, the uranium concentrate must be taken into temporary storage.

Fissile and Fertile Materials

The fabrication of fissile and fertile materials from concentrates was taken up by the Federal Republic in recent years and has, in the case of uranium, resulted in the construction and operation of small-capacity industrial plants. The development work must be continued and should be matched to the specific fuel types needed for the reactors in the Programme.

The same is also true to a limited extent for metallic uranium, particularly for the manufacture and examination of various alloys. Whilst in the case of low-enrichment uranium the progress made by other countries makes it appear more prudent to utilise largely the experience gathered abroad, in the field of higher-alloyed uranium metal Germany's own development efforts seem expedient. In view of the significance of uranium oxide (UO_2) mainly for water-cooled reactors, the relevant development work should be given priority.

Likewise, uranium monocarbide, which is of interest for use in high-temperature reactors, deserves special attention, as do the carbides of thorium which may gain importance for thorium breeder reactors.

Despite the interest which slightly-enriched uranium is experiencing as reactor fuel, there is believed to be no need for erecting a fuel enrichment plant in the Federal Republic. For a number of specialist problems it seems necessary to continue working on new isotope separation methods.

With regard to the development of fast breeder reactors, industrial groups interested in this field should be acquainted with the work performed on plutonium, to an extent enabling such groups to accumulate their own experience in the fabrication of plutonium fuels.

It is also essential for thorium reactors that suitable processes are developed at an early stage for the manufacture of thorium compounds and thorium metal. In this context it must be realized that the radioactive material arising during the reprocessing of thorium into breeder fuel elements necessitates appropriate provisions for the protection of personnel. The same applies to the use of partly-contaminated plutonium and uranium respectively. Work of this type should be performed at least on a semi-technical scale, to provide the experience required for the operation of production facilities. It constitutes an important single task within the overall Programme.

Fuel Elements and Breeder Elements

For the manufacture of fuel elements to be used in thermal reactors, a variety of different processes has been investigated in the past. Some of these appear promising from the economic and technical aspects, but a decision can only be taken after their in-pile behaviour has been sufficiently examined. The German Reactor Programme is centred around fuel elements for water-cooled reactors, high-temperature reactors and a fast breeder reactor. Of importance here are not only the processing stages of the fuel proper, but above all the manufacture and machining of the canning materials as well as their compatibility with the fuel. In the family of reactor fuels the main attention is again focussed on oxides and carbides, and on mixed-fuel systems. Among the canning materials, corrosion-resistant steels and zirconium alloys are regarded as essential.

Because of the relatively large absorption cross-section of the ingredients contained in steels, the adopting of such steels as canning materials necessitates that the walls of the cans must be made as thin as possible. Limitations are the corrosion behaviour, the need to avoid inclusions of foreign matter apt to cause damage to the cans, the shortage of facilities for testing such materials prior to fabrication into fuel elements, and finally certain manufacturing operations, e. g. welding. These problems should be studied independently by the various research hodies.

Extensive experience developed abroad is available on the use of zirconium alloys. Our own work should be centred on the elaboration of technical processes for the manufacture of tubes, with the object of achieving high yields. Here again, developing suitable methods for quality control of such materials is an essential prerequisite. In the course of this development, care must also be taken to reliably determine what quality requirements are necessary and adequate, since the latter have a decisive bearing on the economics of employing such materials.

Beryllium oxide and beryllium metal may become important as special fuels in high-temperature reactors (mixed-fuel system with uranium and beryllium oxide), and also for possible use as fuel element cladding material. To the extent to which relevant research will render encouraging results, specific technological developments should be initiated to form the basis of a practical application.

Testing their in-pile behaviour is one of the foremost conditions applicable to the overall field of fissile and fertile materials of fuel elements and breeder elements respectively. In the Federal Republic very little could be done in the past in this respect, for lack of suitable materials testing reactors. Investigations carried out abroad are by no means sufficient to enable performance of the set tasks. For the future, provisions must be made without fail to ensure that such irradiation tests can be performed on a considerably larger scale, as this is the only manner of selecting suitable materials and for avoiding expensive mal-developments. To this end full use can be made of the materials testing reactors under construction in the Federal Republic. However, no doubt the need will arise for also utilizing the materials testing reactors installed meanwhile within the Euratom area or in other European countries. As soon as satisfactory results are available for individual types, large-scale testing will be essential for the collection of statistical data. For this purpose the general-duty research reactor MZFR should be put to extensive use, at least for testing part of the materials concerned.

In order to permit such irradiation tests to proceed with the necessary scope, substantial promotion by public funds as granted for the few investigations conducted so far will be indispensable in the same way for the future.

Reprocessing

Reprocessing of irradiated fuel is a significant cost element within the fuel cycle. Regarding uranium and plutonium, aqueous processes have been tried out in practice on an industrial scale.

However, there are indications that substantial cost savings can be effected if basic work on pyrometallurgical processes is pursued further, particularly in the case of reprocessing plutonium fuel elements. In the light of the importance which plutonium fuel elements are bound to gain as part of German developments, new approaches must be sought which should include the construction of one or more small-scale pilot plants. Close co-operation with Euratom will be necessary, since work of a similar nature is contemplated under its Second Research Programme. It is very probable that reprocessing of fertile material will have to be undertaken equally for the thorium reactors. On this subject only a little data is available, and for some years to come the bulk of relevant activities will be concentrated on research. Since this problem has great significance for thorium reactors, efforts should be made to have promising research projects followed up by technical developmental work in the next few years.

Storage of Radioactive Wastes

It is planned that radioactive wastes be disposed of initially to several intermediate storage depots to be set up as a rule in conjunction with large research centres or reactor stations.

These will serve for the collection of waste arising from the application of radioisotopes and from research performed by small and medium-size laboratories in the respective areas. Later on, part of the radioactive wastes will be transferred from intermediate storage to the final disposal sites. Relevant technical development work is being carried on in close cooperation with health physics tasks, and is described in more detail under section B 3.

c) Reactor materials

Despite extensive work in other countries, in the field of reactor materials considerable interest exists in the further development of steels for reactor pressure vessels. In this context the testing of materials in reactors is considered to be necessary on a larger scale.

Beryllium continues to merit considerable attention both as a structural material and as a moderator. The investigations conducted on it abroad have not arrived at the same results. This material may become attractive for applications beyond the field of nuclear energy. Apart from research on basic problems, specific technological development work should be carried out in this particular area.

In the case of mineral materials, special attention should be devoted to investigating the possibilities of adopting pre-stressed concrete for reactor pressure vessels. For safety reasons and because of a potential reduction in the specific capital investment, this approach might be worthwhile for several reactor construction projects in progress within the Federal Republic.

d) Process Engineering, Reactor Components

The solution of engineering problems concerned with plant safety are at least as important as nuclear questions are for the design of reactor systems. Main issues in this respect are concentrated on heat transfer problems from fuel elements to primary loop coolant, and from primary loop coolant to heat exchangers. Additional studies should be expedited in connection with the known instabilities in water-steam mixtures, and the separation of water from steam. For gas-cooled reactors the further development of blower-bearings will be essential since there are still no proven designs available which are both oil-free and leak-tight.

To permit the use of sodium as a coolant in fast breeder systems it will be important that large-scale test facilities and test loops are set up for examining specialist problem areas and for testing corrosion behaviour.

3. HEALTH PHYSICS

All sections of the Research and Development Programme set out here are associated with health physics tasks which, as a rule, do not require special mention within the range of this programme. Only the sections on biology and chemistry make reference to extensive research and development work in the health physics field. A major sphere which can be kept separate from other research and development activities is the question of how to make radiation protection measures in nuclear installations more effective, less complicated and less expensive. Expenditure on health physics constitute an essential element of the overall cost of those installations.

Technical health physics work should be given priority as far as research and development in the following sectors is concerned:

Development of small-size plants for preliminary reprocessing of radioactive wastes at the location where they arise;

Shipping containers and shipping procedures;

Investigations on geological strata suited for underground storage of radioactive waste;

Planning, design and construction of a permanent storage depot in a salt mine (possibilities for disposal elsewhere, e. g. in the sea, should be studied on an international basis).

Safety engineering in nuclear installations: materials problems (see sections II. A.2 and II. A.3); safety containments for reactors (such as pre-stressed concrete, multi-skin vessels), and ventilating systems;

Preventing the spreading of radioactivity released from nuclear installations: meteorological, hydrological and oceanographic issues (see also section I. A. 4);

Participation in the SPERT programme of the United States Atomic Energy Commission.

4. ELECTRONIC AND CONTROL ENGINEERING

All applications of nuclear energy depend on the use of instrumentation in various degrees. Expenditure, mainly on electronic measuring instruments, constitutes the bulk of the overall cost involved in a large number of experiments and practical uses. Equipment of this type is at the present time procured abroad to a large extent. Only a small portion of the instrumentation is manufactured by the German industry, others are being developed and manufactured by research institutes in connection with special applications. Advances made in control engineering are reflected directly on experiments and applications. Therefore, any dependence on foreign suppliers handicaps an interest in Government promotion with a view to an expansion of control engineering in the Federal Republic. Two approaches appear feasible:

Development of equipment either by institutes or by way of development contracts awarded to industry by institutes to permit the performance of specific tasks; and research contracts to the interested industry.

Very small funds are needed to expand the existing capacity of the relevant manufacturers, which could then be employed for the promotion of new tasks of general interest. Industry alone cannot be expected to perform this work to the extent desirable, since the market for equipment produced as a result of such development activities is substantially smaller than that which exists in larger countries.

5. RADIATION SOURCES

Radioisotopes

The continually-increasing number of applications for nuclear radiation requires the availability of radiation sources suited for the purposes concerned. In the majority of cases such sources are radioisotopes produced in nuclear reactors. Currently, the bulk of the radioisotopes used in the Federal Republic have been produced abroad. Fabrication of tracer compounds takes place partly in foreign countries, partly in the Federal Republic. Should the demand for radioisotopes rise further, their fabrication in the Federal Republic should be taken into consideration. This will be necessary in any case for short-lived radioisotopes which cannot be transported over long distances.

Accelerators and X-ray Equipment

For irradiation by weak-ionizing radiation (electrons) such as employed for foodstuffs and plastics, large high-power electron accelerators, e.g. linear accelerators are required. But, except for a few exceptions such as X-ray tubes, such equipment has not been developed in the Federal Republic to date. If the demand in this branch continues to increase, promotion of the development of such equipment would be recommended.

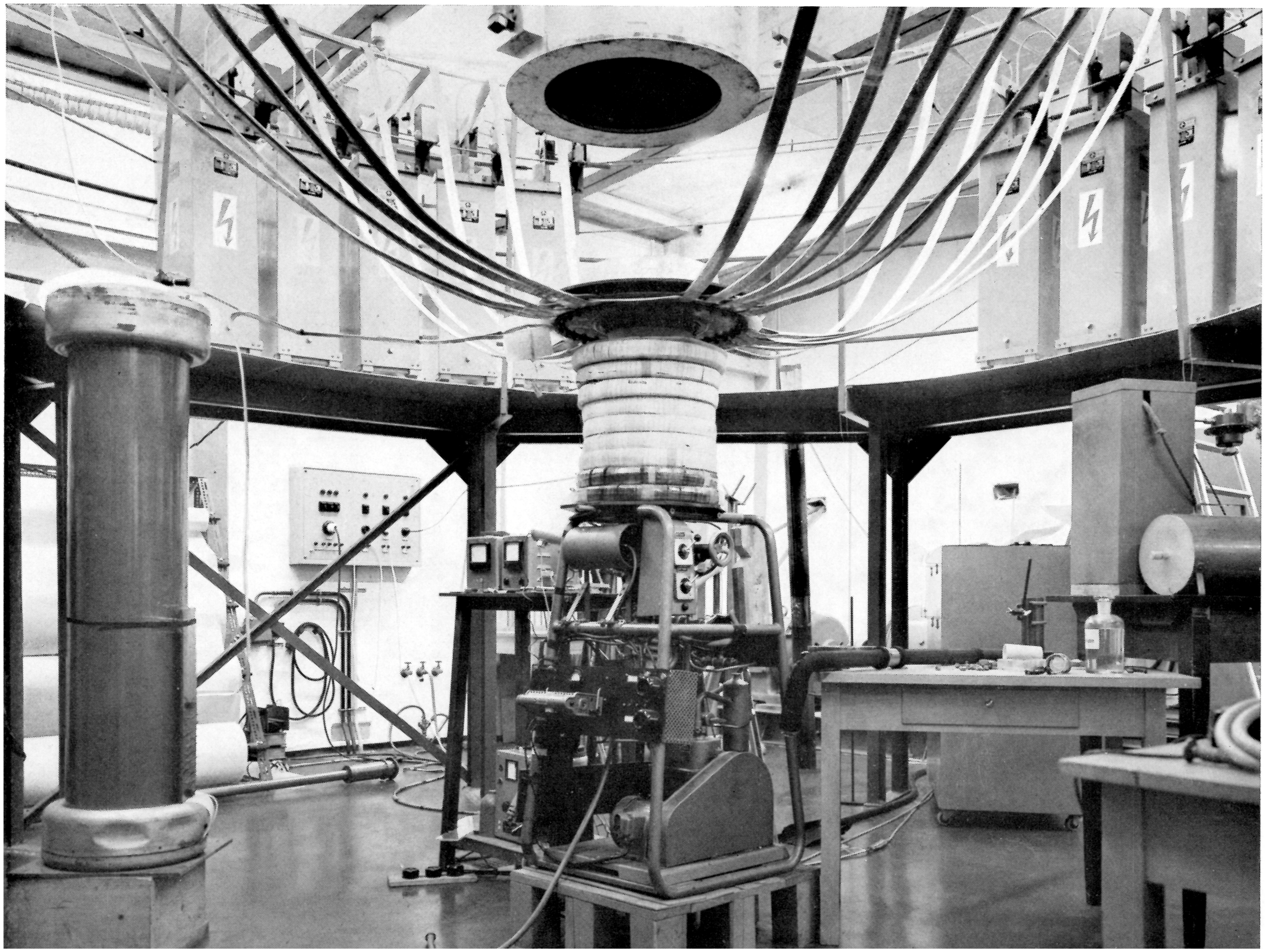
Accelerators for high-ionizing Radiation

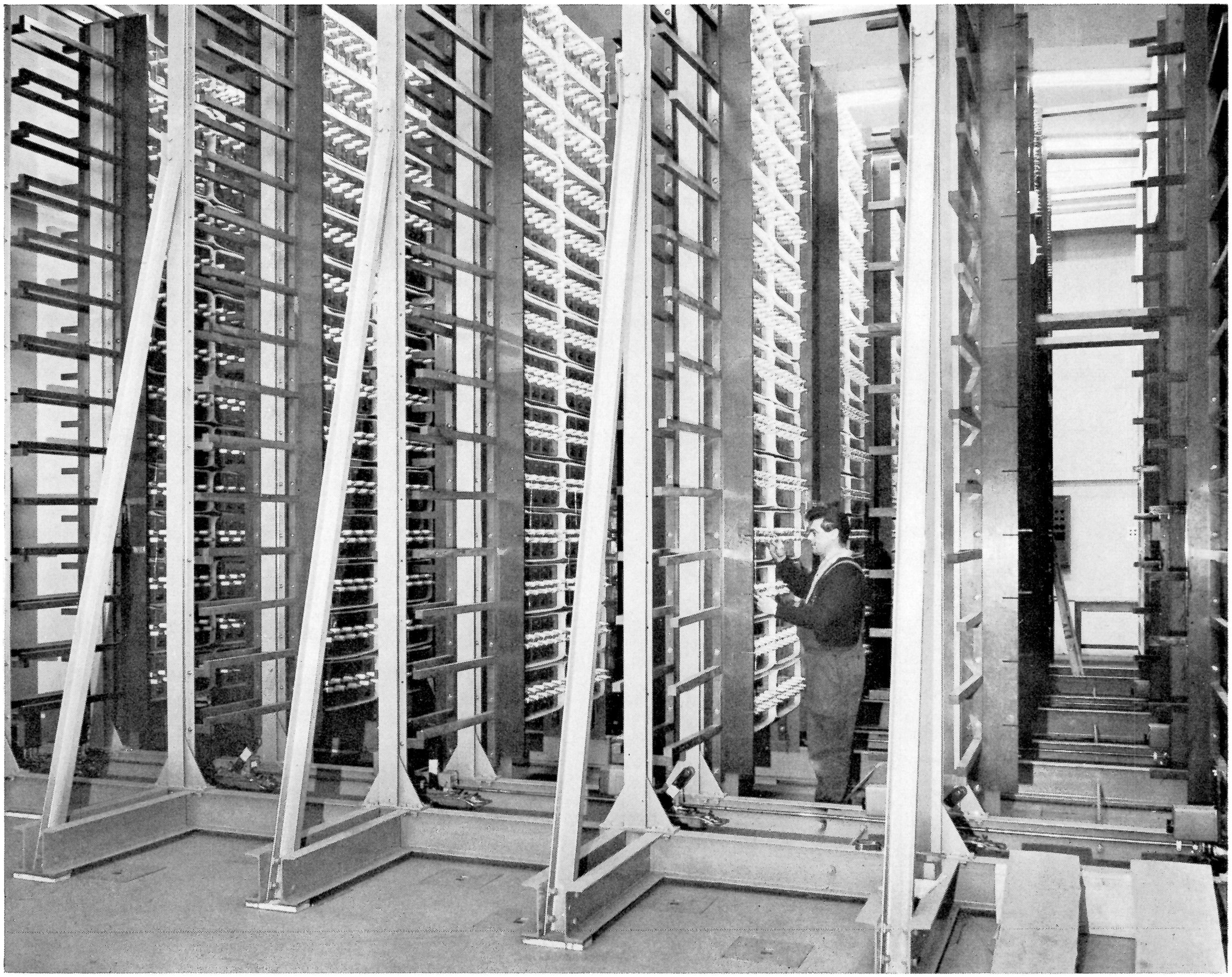
In nuclear physics, and to a certain degree in solid-state physics, accelerators for heavy particles up to energies in the order of 50 MeV are frequently used. So far, a German development exists only for a cyclotron. Intensified promotion would be desirable both in view of the benefit derived therefrom for German research and the significance which outstanding technical achievements have for the participating firms.

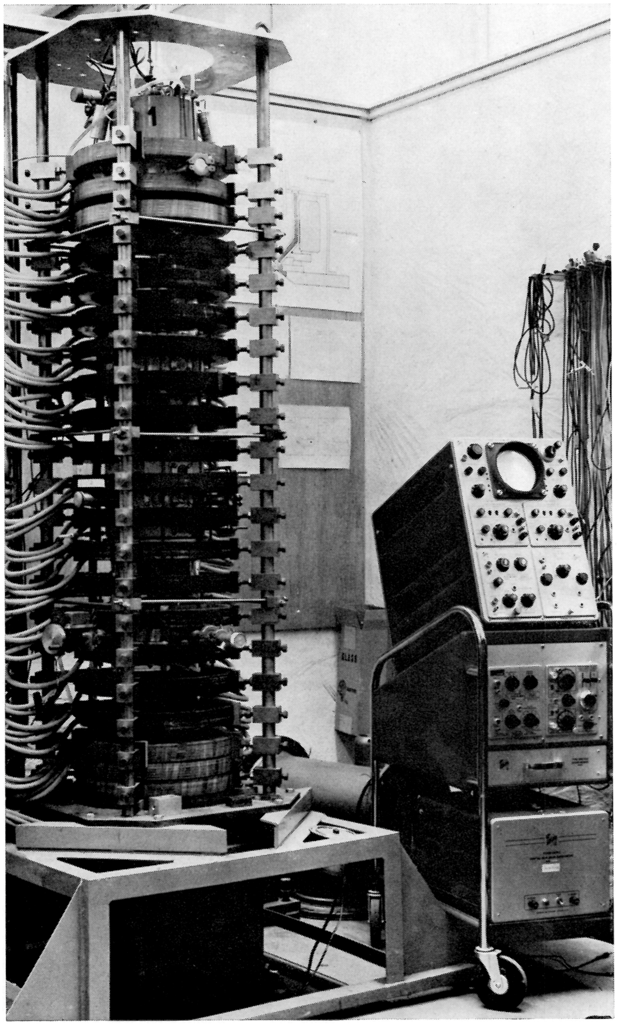
Chemical Reactor

In the majority of radio-chemical processes the fission products of a reactor are the most effective source of radiation. For the study of the fundamentals of radio-chemical processes, in-pile tests with small uranium samples are sufficient. In the event of radio-chemical production processes being seriously contemplated, the design of specific reactor types suited for the purpose will have to be undertaken.

One of the centres of big science in Germany is the Plasma Physics Institute at Garching near Munich. The picture shows an experimental assembly for a stabilized linear pinch. Upon discharge of the 160 kJoule battery a current of 1 million A will for some microseconds flow in the deuterium gas of the assembly.

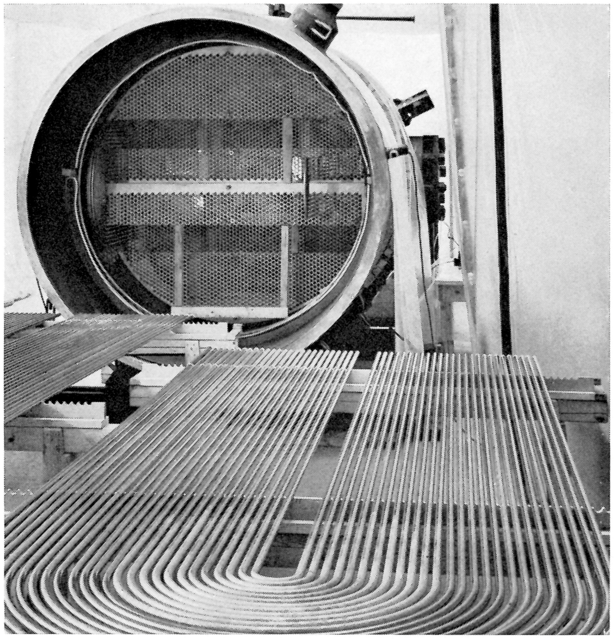


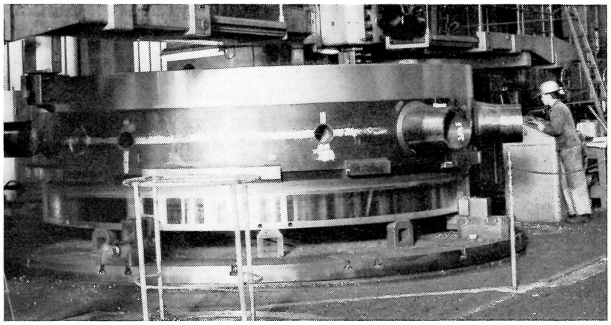


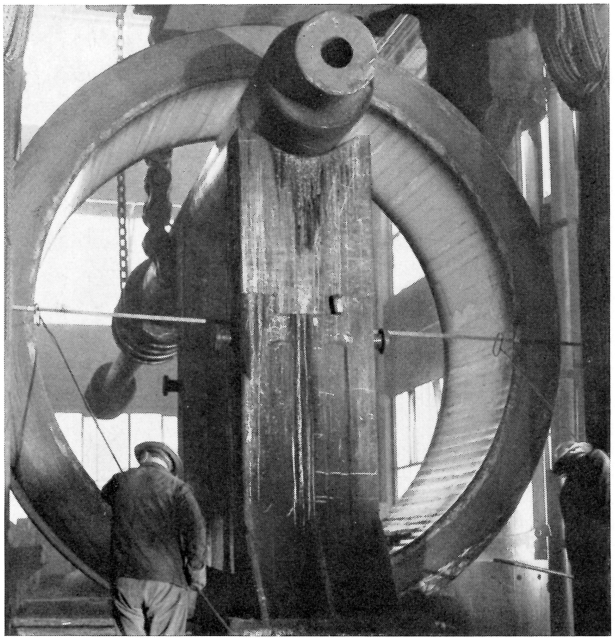


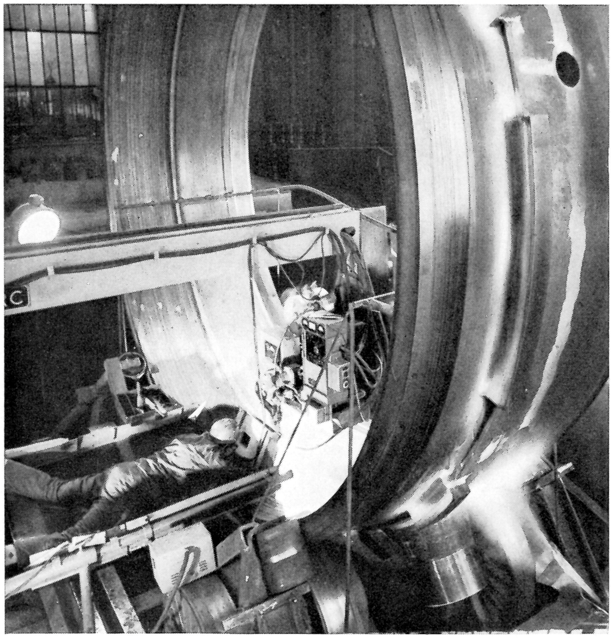
A capacitor battery of 1.5 MJoule capacity was set up for a current pulsation plant at the Garching plasma institute (picture on the opposite page). "Cabinet" is the name of an apparatus used to investigate a stationary cold plasma discharge (picture on the left). The apparatus shall above all yield information on the diffusion of charge carriers in magnetic fields.

The first large nuclear power station with an electric output of 237 MW is now under construction at Gundremmingen on the upper Danube (picture on the left). On the lower right: a view of the bulding site in spring 1964, on the upper left: a photo taken during the fabrication of the steam generator for Gundremmingen. Even though the boiling water reactor of the power station is of American design, most of the components of the station – above all the major ones – are being manufactured in Germany.

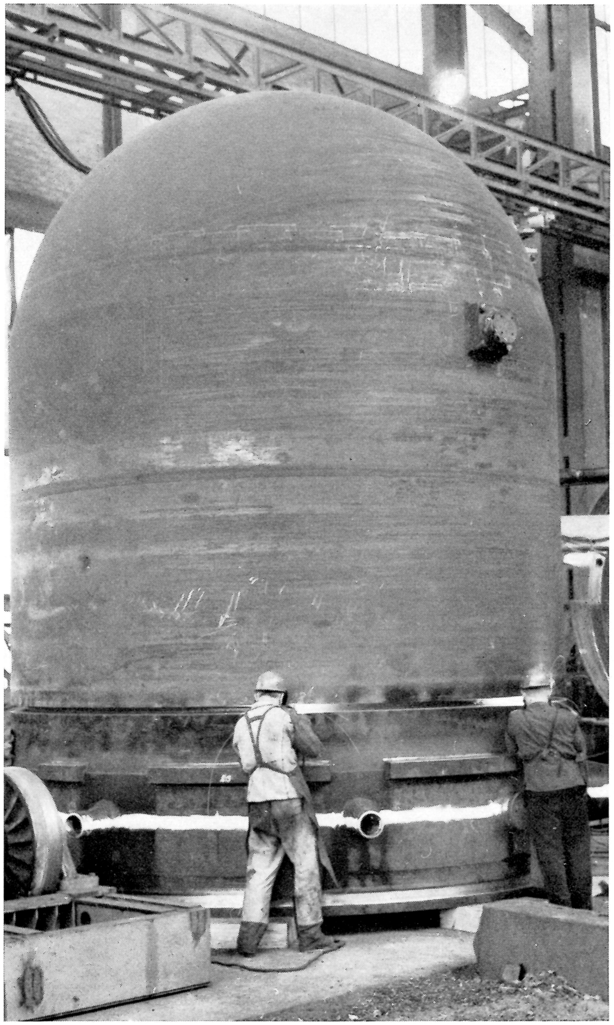


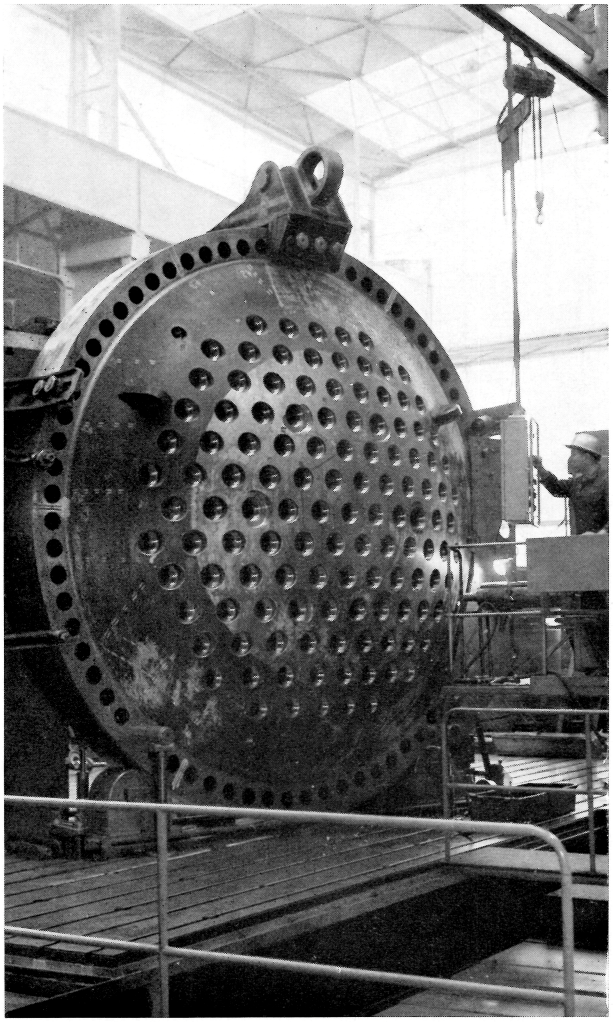




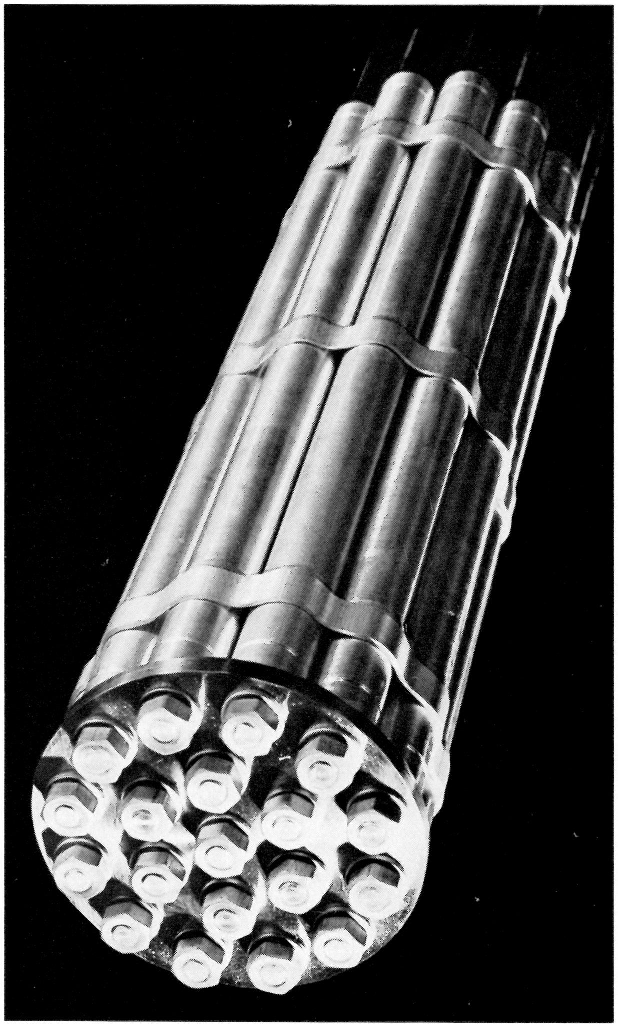

RC

This is how the pressure vessel for the multi-purpose reactor was manufactured: on the opposite page, extreme left: a picture of the complete forging of the flange ring out of a 100-t block; in the next series of pictures the turning of the flange ring on a vertical boring mill is to be seen, below the stainless steel plating and at the bottom the welding of the last circular bead on the finished pressure vessel; on the lower left of this page: a picture showing how the pressure vessel is assembled before the last circular bead is welded, and on the lower right: the lid of the pressure vessel while the holes for the 121 fuel element tubes are being bored.





Along with the development of a reactor industry in the Federal Republic of Germany the manufacture of nuclear fuel and reactor fuel elements was initiated and promoted. The picture on the left below shows some bunches of plate-type fuel elements such as they are to be used in the Geesthacht swimming-pool reactor. On the right below: a fuel element consisting of a bunch of rods for the Euratom ECO-project. On the opposite page there is a photomicrograph of uranium bodies.



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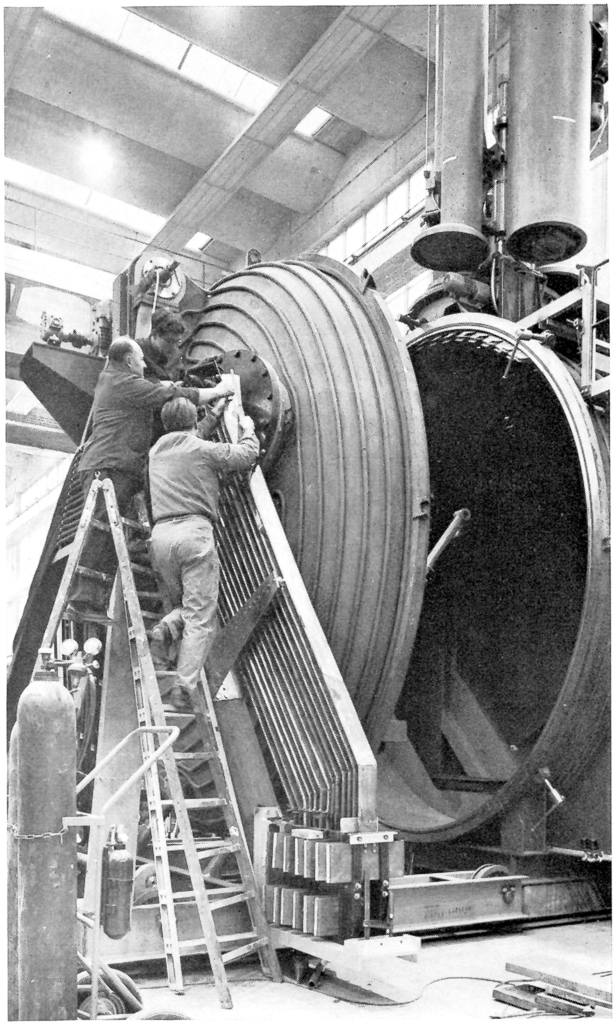
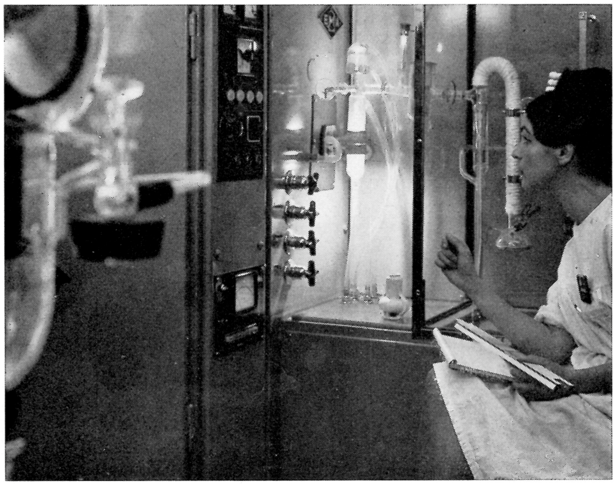
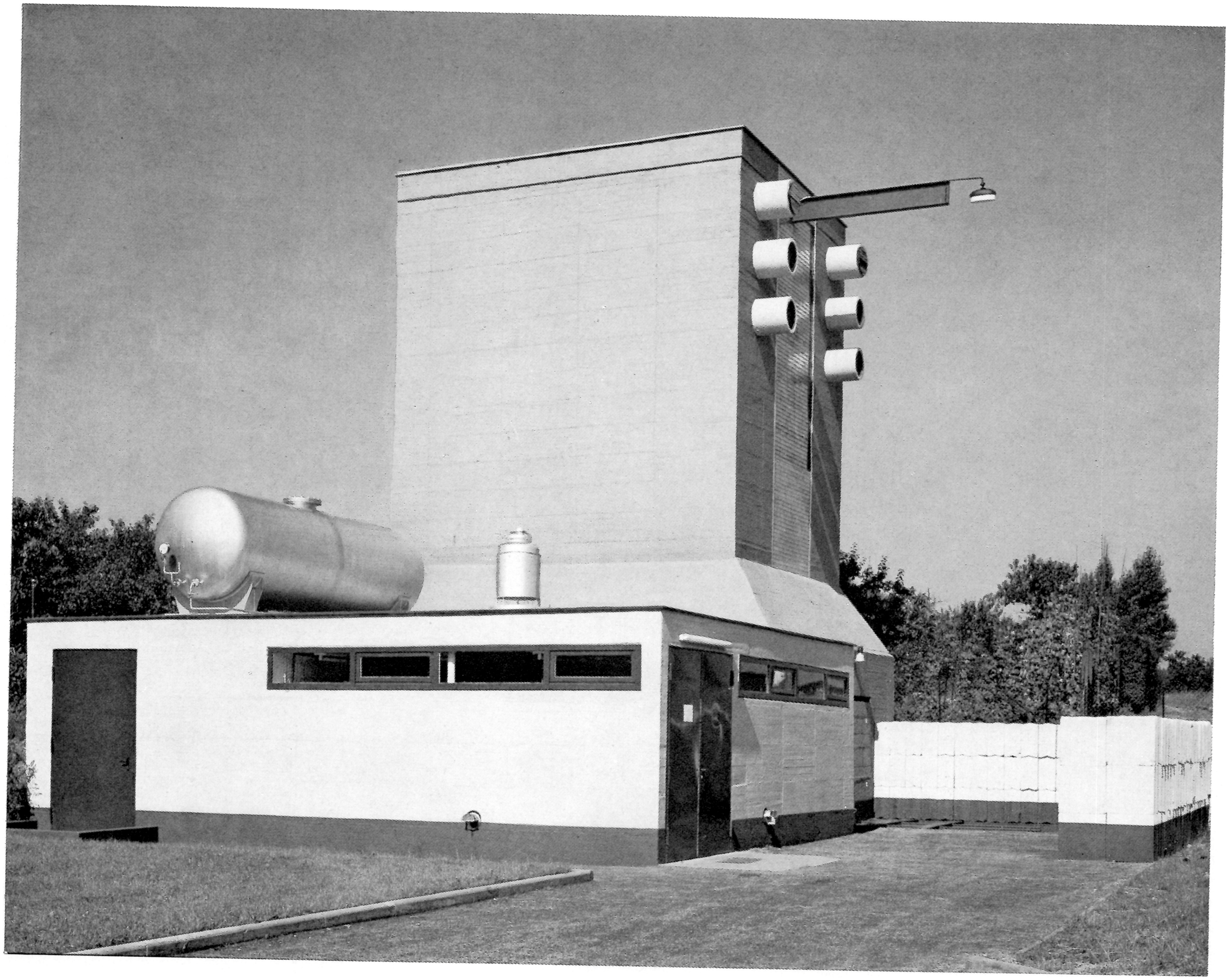
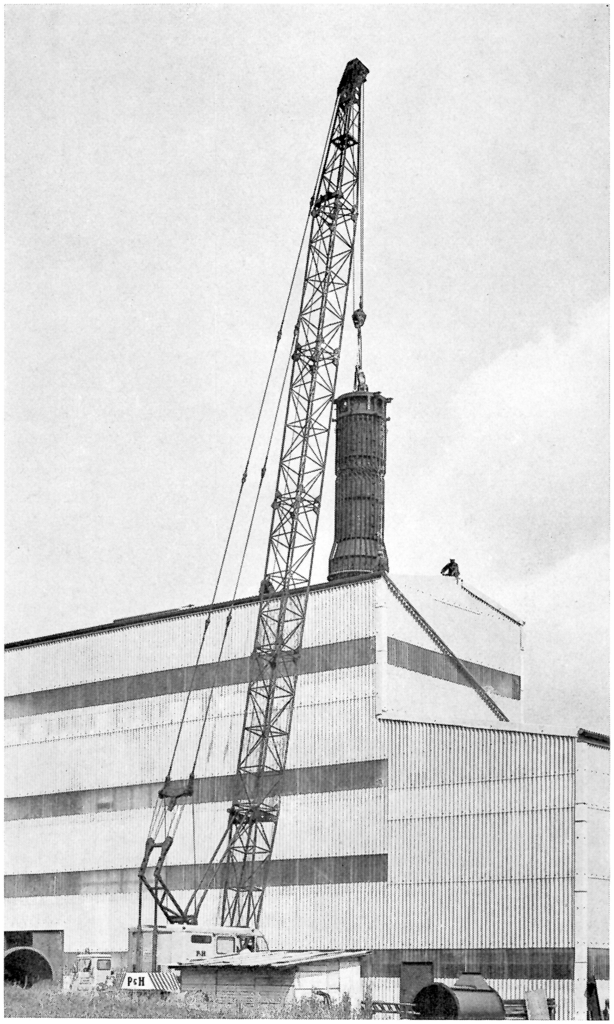
Since nuclear engineering calls for high qualities it has a stimulating effect on many industrial techniques. On the left below you will see a vacuum induction furnace for melting and casting of high quality special materials for reactor construction, on the right below: a high-temperature extraction plant for the accurate determination of the gas content of reactor construction materials and fuel elements, on the opposite page an industrial irradiation station with a 3 MeV Van-de-Graaff electron accelerator (radiation capacity 4.5 k W).









This 5 MW experimental plant is used to familiarize engineers and scientists with the sodium cooling technique. The picture shows the insertion of an oil-fired sodium vessel.

C. CONSTRUCTION OF NUCLEAR INSTALLATIONS

1. NUCLEAR REACTORS

On the basis of the present status and the criteria set out above for drawing up a reactor programme, construction of the following power reactors under the short-range programme may be expected to be initiated or proceeded with during the next five years:

a) Reactors of proven design in the medium-to-high output range, constructed independently by German firms and requiring little governmental promotion (related, for example, to the kilowatt of installed capacity). This means that German industry will be taking up and continuing the construction of reactor types already tried out abroad. Reactors of this category should, for demonstrating their potential economic performance, be constructed in the sizes consistent with the risks involved in the erection of Germany's own "first" installations.

b) Reactors which are first units of a type not tried out to economic performance even in foreign countries. By nature, reactors of this category require substantial promotion by the Government. To the practical limit, experimental reactor plants are scheduled for construction initially of such types as will permit judging whether the particular reactor type is promising under both technical and economic considerations. Reactors of this category should be constructed in reasonable-sized units since in their case it is not the achievable cost of power but the technical and economic know-how to be gained which will be decisive.

Considering the current status of developments in Germany, the gathering of construction and operating experience is of paramount importance. It can therefore be expected, and demanded, that in the course of the next five years perhaps two plants under (a) above and at least three plants under (b) above will be continued or commenced. In addition, one marine reactor should be built.

Under the long-range programme there appears to be no indication of the construction of full-scale power plants during the next five years beyond the materialization of small-capacity units as part of the development efforts.

2. REPROCESSING OF SPENT FUEL

In the light of the significance of varied technical difficulties experienced in the reprocessing of spent fuel, it is considered essential that initially a small plant for reprocessing natural uranium and slightly-enriched uranium fuel elements be designed and built at an early state. Such a plant is scheduled to operate on the well-proven aqueous process. The contemplated design period is one year, which means that construction and commissioning of the plant will be feasible within the next five years. The plant is to be designed for a capacity of about 30 metric tons per annum of natural uranium and could, therefore, when completed, be employed to full capacity without impairing the interests of Eurochemic in this respect.

Certain aspects speak in favour of the construction also of a smaller plant for aqueous reprocessing of fast breeder fuel elements. A decision on the materialization of such a plant can be expected during the next 1–2 years.

3. WASTE STORAGE

As outlined under the sections on "Storage of radioactive Wastes" and "Health Physics", the establishment of a few intermediate storage depots appears to be a priority task. On the project of an ultimate disposal depot to be located in a salt stratum, short-term preparations should be commenced for the selection of a suitable site and for the drawing-up of a concrete proposal aimed at the construction of such a plant within the next few years.

III. FINANCE REQUIREMENTS

For materializing the programme set out above a substantial increase in expenditures during the next five years will be essential. This increase in the amount of funds required will not have to be continued at the same rate during the subsequent period, but may be expected to settle at a certain percentage of the German gross national product as yet indeterminable.

Despite the marked expansion which related work has recently gone through in the sphere of technical development, basic research must still be intensified considerably in the course of the five-year period of the programme, if it is only to approach the level already achieved today in countries with comparable economic potential. Thus an ascending rate of about 20% is contemplated which would involve DM 1.1–1.2 billion for the period 1963–1967. Such expenditures are not intended to be concentrated on the setting-up of large new research establishments, but mainly for the promotion and expansion of existing institutions. These expenditures represent a fraction of the total finance requirements for research and universities.

The figures given relate to basic research only. In contrast with the subdivision of the programme, the funds required for applied research are stated separately. They are estimated to amount to 30–40% of the funds for basic research, with the bulk of this centred on the research establishments.

In this context, applied research is understood to cover both work with a close affinity to basic research and work more along the lines of developments. The annual ascending rate is thought to be roughly identical to that for basic research. If one considers that any advancement of our technical and industrial projects in this field more than in any other area of activity depends on successful research work and the results thereof, then the overall expenditure appears reasonable.

A breakdown of the funds envisaged for developing the nuclear engineering sector and for the construction of nuclear installations cannot be given in this context, since the plants come under part of the development efforts, and are not industrial installations although industrial firms participate in the construction and operation of such plants. According to various separate estimates prepared, the total capital investment for the next five years is believed to be in the region of DM 1.0–1.1 billion.

Compared with the spending of public funds on promotion measures in the past years, the growing significance of the development sector can be clearly recognized. The estimates given above also include considerable expenditure for work on the future construction ranges of fast and thermal breeder reactors. Not included in the totals is the capital investment required for large-size nuclear power stations.

From the long-term nature of the programme the necessity arises of ensuring its financing over long time periods. In addition, care should be taken to ensure that a materialization of the programme is not impaired by rigid mutual interlacing of promotion measures.

The substantial support contemplated, during the period in question, for reactor types of the short-range programme would appear indispensable, since at a later date industrial firms will be in a position to construct advanced and technically attractive reactors only if in the meantime they are able to amass the necessary technical experience on reactors of a more conventional type. For that very reason strong impetus should be given within the framework of public spending on overall promotion measures that the construction of German-developed nuclear reactors is commenced as early as possible on the basis of contracts awarded by the German utility companies, even if such action calls for unusual measures. In the event that such an approach were not found to be feasible, then construction based on contracts by the Government would have to be taken into consideration. If this target were not achieved, the heavy expenditures on research and development, as envisaged herein, would benefit the German economy only to a small degree not justifiable in the near and–still worse–in a more distant future, in the light of the paramount importance of the activities in this overall field.

IX COMMITTEE OF THE GERMAN BUNDESTAG FOR NUCLEAR ENERGY AND WATER ECONOMY

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X THE DEUTSCHES ATOMFORUM E.V.*)

The Deutsches Atomforum was founded in Karlsruhe, May 26, 1959, by the fusion of four German associations active in the field of nuclear energy. Its seat is Bonn. The Deutsches Atomforum promotes the peaceful use of nuclear energy thus pursuing aims of common interest.

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Purpose and Objectives
are based on the necessity to promote the peaceful use of nuclear energy. The Deutsches Atomforum cooperates successfully with personalities, institutions, agencies, and organisations that are active in this particular field, thus implementing its statutes which demand "that all aspirations be furthered which are connected with the development and use of nuclear energy for peaceful purposes". This goal shall be reached by:

1. dealing with technical and scientific problems in a national and international framework;
2. working out technical rules, instructions and standards;
3. promoting the discussion about common aspirations of firms interested in the peaceful use of nuclear energy;
4. collaborating with the legislative and executive branches of the Federal Republic and the Laender;
5. keeping in touch with similar institutions abroad and with international nuclear organisations;
6. informing the public about the peaceful use of nuclear energy;
7. organizing mobile exhibitions about nuclear energy;
8. dealing with problems of space research and astronautics in close cooperation with the Federal Ministry for Nuclear Energy.

Many members of the Deutsches Atomforum contribute on an honorary basis to the fulfilment of these various tasks. The following working committees have been created for this purpose:

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II Press and Public Relations
III Law and Administration
IV Trade and Industry
V Foreign Relations
VI Fairs and Exhibitions

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V Dr. F. A. Prentzel
VI Dr.-Ing. H. Roemer

Membership

In accordance with the function of the Deutsches Atomforum its members are not only persons directly working in the field of nuclear energy. Members of parliament, politicians of all parties represented in the Bundestag, the authoritative ministers of the Federal Republic and the Laender, scientists, representatives of industry, technical science and medicine as well as people from all walks of life have also joined the Atomforum.

Foratom

The Deutsches Atomforum is one of those organisations which in Paris, July 12, 1960 founded the European Atomic Forum, Foratom, and in which also fellow associations of Austria, Belgium, France, Great Britain, Italy, Luxemburg, the Netherlands, Norway, Portugal, Spain and Switzerland are represented.

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XI REAKTOREN IN DER BUNDESREPUBLIK DEUTSCHLAND
REACTORS IN THE FEDERAL REPUBLIC OF GERMANY

A. Forschungsreaktoren (Forschungs-, Unterrichts- und Prüfreaktoren) Research Reactors (Research-, Training- and Test Reactors)

Standort und Bezeichnung Location and Name	Reaktortyp Reactor type	Verwendungszweck Purpose	Betreiber Operator	Wärmeleistung in kW Thermal Output	maximaler thermischer Neutronenfluß max. Thermal Neutron Flux (n/cm^2sec)	Kühlmittel Coolant
1. Garching b. München (FRM)	Schwimmbad	Forschung	Laboratorium f. Technische Physik der TH München	1000	$2{,}5 \cdot 10^{13}$	H_2O
2. Frankfurt a. Main (FRF)	Water boiler (homogener Lösungsreaktor)	Forschung	Institut f. Kernphysik der Universität Frankfurt a. Main	50	ca. 10^{12}	H_2O
3. Berlin-Wannsee (BER)	Water boiler (homogener Lösungsreaktor)	Forschung	Hahn-Meitner-Institut f. Kernforschung Berlin	50	ca. 10^{12}	H_2O
4. Geesthacht/Elbe	Schwimmbad mit zwei Kernen	Forschung u. Untersuchungen zur Entwicklung von Schiffsreaktoren (z. B. Abschirmung; Korrosion)	Gesellschaft f. Kernenergieverwertung in Schiffbau und Schiffahrt mbH, Hamburg	5000	$3{,}2 \cdot 10^{13}$	H_2O

Moderator Moderator	Kernbrennstoff Fuel	Herstellerfirma und deutsche Hauptkontraktfirma Designer and principal German Contractor	Auftraggeber Ordered by	Finanzierung Financed by	Stand Anfang 1964 Status: Early 1964
H_2O	angereichertes Uran (20%) 4 kg ^{235}U	AMF (American Maschine & Foundry Co. - USA) mit MAN	Land Bayern	Land Bayern und Bund	in Betrieb seit 31. 10. 1957
H_2O	20% angereich. Uranylsulfat in wäßriger Lösung (ca. 1,4 kg ^{235}U)	Atomics International (USA) mit AEG, BBC, Mannesmann und SSW	Land Hessen	Farbwerke Hoechst (Reaktor), Bund (Geräte), Stadt Frankfurt (Gebäude)	in Betrieb seit 10. 1. 1958
H_2O	20% angereich. Uransulfat in wäßriger Lösung (ca. 1,3 kg ^{235}U)	Atomics International (USA) mit AEG, Borsig, Pintsch-Bamag und SSW	Senat Berlin	Land Berlin und Bund	in Betrieb seit 24. 7. 1958
H_2O	angereich. auf 90% ^{235}U 1. 5,4 kg 2. 5,4 kg	Babcock & Wilcox Co. (USA) mit Deutsche Babcock & Wilcox	Gesellschaft f. Kernenergieverwertung in Schiffbau und Schiffahrt mbH, Hamburg	Bund 60%, Bremen, Hamburg, Niedersachsen, Schleswig-Holstein (40%)	in Betrieb seit 23. 10. 1958 in Betrieb seit 16. 3. 1963

Standort und Bezeichnung Location and Name	Reaktortyp Reactor type	Verwendungszweck Purpose	Betreiber Operator	Wärmeleistung in kW Thermal Output	maximaler thermischer Neutronenfluß max. Thermal Neutron Flux (n/cm^2sec)	Kühlmittel Coolant
5. Leopoldshafen bei Karlsruhe (FR 2)	Schwerwasserreaktor	Forschung; Prüfung von Brennelementen u. Material; Produktion von Radioisotopen	Kernreaktor Bau- u. Betriebs-GmbH, Karlsruhe	12000	$3 \cdot 10^{13}$	D_2O
6. Jülich (MERLIN)	Schwimmbad	Forschung; Materialuntersuchungen, Produktion von Radioisotopen	Kernforschungsanlage Jülich (KFA Jülich)	5000	ca. $8 \cdot 10^{13}$	H_2O
7. Jülich (DIDO)	Schwerwasser	Forschung; Materialuntersuchungen, Produktion von Radioisotopen	Kernforschungsanlage Jülich (KFA Jülich)	10000	ca. $1{,}8 \cdot 10^{14}$	D_2O
8. Garching b. München (SAR)	Argonaut	Ausbildung u. Forschung	Siemens-Schuckertwerke AG, Erlangen	1 (kurzzeitig 10)	bei 10 kW 10^{11}	H_2O
9. Großwelzheim bei Aschaffenburg	Argonaut	Prüfreaktor	AEG	0,1	$3 \cdot 10^{8}$	H_2O

Moderator Moderator	Kernbrennstoff Fuel	Herstellerfirma und deutsche Hauptkontraktfirma Designer and principal German Contractor	Auftraggeber Ordered by	Finanzierung Financed by	Stand Anfang 1964 Status: Early 1964
D_2O	Natururan Thorium	Deutsche Industriefirmen	Kernreaktor Bau- u. Betriebs-GmbH, Karlsruhe	Bund und Land Baden-Württemberg (Industrie)	zum ersten Male kritisch 7. 3. 1961, volle Leistung 19. 12. 1962
H_2O	angereich. Uran (über 80%) 2,7 kg ^{235}U	The Nuclear Power Group Ltd., Großbritannien	Land Nordrhein-Westfalen	Land Nordrhein-Westfalen und Bund	zuerst kritisch 23. 2. 1962
D_2O	angereich. Uran (über 90%) 1,1 kg ^{235}U	Nachbau deutscher Firmen nach Konstruktion von Head Wrightson Processes Ltd., Großbritannien	Land Nordrhein-Westfalen	Land Nordrhein-Westfalen und Bund	zuerst kritisch 14. 11. 1962
Graphit und H_2O	angereich. Uran (20%) 2 bis 5,7 kg ^{235}U	Siemens Schuckertwerke nach Argonne National Laboratory, USA	Siemens-Schuckertwerke	Siemens-Schuckertwerke	in Betrieb seit 23. 6. 1959
Graphit und H_2O	angereich. Uran (20%) 2 bis 5,7 kg ^{235}U	AEG nach Argonne National Laboratory USA	AEG	AEG	in Betrieb seit 27. 1. 1961

Standort und Bezeichnung Location and Name	Reaktortyp Reactor type	Verwendungszweck Purpose	Betreiber Operator	Wärmeleistung in kW Thermal Output	maximaler thermischer Neutronenfluß max. Thermal Neutron Flux (n/cm^2sec)	Kühlmittel Coolant
10. Leopoldshafen bei Karlsruhe	Argonaut	Ausbildung, Forschungsarbeiten	Kernreaktor Bau- u. Betriebs-GmbH, Karlsruhe	3,5 bis 6,5 W	$8 \cdot 10^7$	H_2O
11. * Berlin-Charlottenburg, TU	Siemens-Unterrichts-Reaktor	Unterricht	Institut f. Allgemeine u. Kernverfahrenstechnik der TU Berlin	0,1 W (kurzzeitig 10 W)	$5 \cdot 10^6$	
desgl. TH Stuttgart			Institut für Hochtemperaturforschung			
TH Darmstadt,			Institut für Reaktortechnik			
Garching			SSW			
12. Braunschweig (PTB-Meßreaktor)	Tankreaktor	Meßzwecke	Physikalisch-Technische Bundesanstalt	1 000	$6 \cdot 10^{12}$	H_2O
13. Mainz (FRMZ)	Triga-Pulsreaktor	Forschung	Institut für Anorganische Chemie und Kernchemie der Universität Mainz	100 Puls: 250 MW $^1/_{100}$ sec	ca. $1 \cdot 10^{12}$ Puls: ca. $8 \cdot 10^{15}$	H_2O

* In dieser Position sind vier Unterrichtsreaktoren des gleichen Typs zusammengefaßt.

Moderator Moderator	Kernbrennstoff Fuel	Herstellerfirma und deutsche Hauptkontraktfirma Designer and principal German Contractor	Auftraggeber Ordered by	Finanzierung Financed by	Stand Anfang 1964 Status: Early 1964
Graphit und H_2O	angereich. Uran (20%) a) therm.: 5,6 kg b) schnell: 90 kg	Arb.-Gem. SSW, Lurgi u. Pintsch-Bamag nach Argonne Nat. Laboratory, USA	Gesellschaft für Kernforschung mbH, Karlsruhe	Bund (75%) und Land Baden-Württemberg (25%)	im Umbau
Poly-äthylen	angereich. Uran (20%) 0,7 kg ^{235}U	Siemens-Schuckertwerke AG	Senat Berlin	Bund	in Betrieb seit 17. 7. 1963
				Bund und Land Baden-Württemberg	im Bau
				Land Hessen	23. 9. 1963
				SSW	28. 2. 1962
H_2O	angereich. Uran (90%) a) 3,2 kg ^{235}U b) 2 · 2,9 kg ^{235}U	Deutsche Babcock & Wilcox	Physikalisch-Technische Bundesanstalt	Bund	im Bau
Zirkon-hydrid	angereich. Uran (20%) 2,2 kg ^{235}U	General Atomic Division der General Dynamics Corp. (USA)	Land Rheinland-Pfalz	Bund	im Bau

Standort und Bezeichnung Location and Name	Reaktortyp Reactor type	Verwendungszweck Purpose	Betreiber Operator	Wärmeleistung in kW Thermal Output	maximaler thermischer Neutronenfluß max. Thermal Neutron Flux (n/cm^2sec)	Kühlmittel Coolant
14. SNEAK Leopoldshafen bei Karlsruhe	Plutonium	Entwicklung eines schnellen Brüters	Gesellschaft für Kernforschung mbH, Karlsruhe			Luft
B. Leistungsreaktoren Power Reactors						
1. Kahl/Main	Siedewasser	Stromerzeugung	RWE, Essen (80%); Bayernwerk, München (20%)	60000 (thermische Leistung) 15000 (elektrische Leistung)	$7 \cdot 10^{13}$	H_2O
2. Jülich	Gasgekühlter Hochtemperaturreaktor (Kugelhaufenreaktor)	Stromerzeugung	AVR, Düsseldorf (Kommunale Energieversorgungsunternehmen)	49000 (thermische Leistung) 15000 (elektrische Leistung)	$2 \cdot 10^{14}$	Helium-Neon-Gemisch
3. Karlsruhe	Mehrzweck-Forschungsreaktor, Druckkesselreaktor	Materialprüfung, Isotopenproduktion, Forschung, Stromerzeugung	Gesellschaft f. Kernforschung, Karlsruhe	200000 (thermische Leistung) 50000 (elektrische Leistung)		D_2O

Moderator Moderator	Kernbrennstoff Fuel	Herstellerfirma und deutsche Hauptkontraktfirma Designer and principal German Contractor	Auftraggeber Ordered by	Finanzierung Financed by	Stand Anfang 1964 Status: Early 1964
	0,3 t Plutonium 0,5 t Uran	Kernreaktor Bau- u. Betriebs GmbH, Karlsruhe/SSW	Gesellschaft für Kernforschung mbH, Karlsruhe	Bund und Land Baden-Württemberg berg	im Bau
H_2O	UO_2 mit 2,6% Anreicherung	AEG mit General Electric (USA)	RWE und Bayernwerk	RWE: 28 Mill. DM Bayernwerk: 7 Mill. DM	in Betrieb seit 13. 7. 1961 m. 75%, seit 3. 1. 1962 Vollast
Graphit	Anreicherung 20% Urankarbid (UC) mit Thoriumkarbid als Brutstoff in Graphitkugeln	BBC – Krupp	AVR Düsseldorf	AVR: 20 Mill. DM Bund: 20 Mill. DM	seit Januar 1961 im Bau
D_2O	natürliches UO_2	Siemens-Schuckertwerke, Erlangen	Bund, Land Baden-Württemberg u. Elektrizitätswerke in Baden-Württemberg	Bund: 127 Mill DM, Baden-Württemberg u. Elektrizitätswerke in Baden-Württemberg: 30 Mill. DM	seit Ende 1961 im Bau

Standort und Bezeichnung Location and Name	Reaktortyp Reactor type	Verwendungszweck Purpose	Betreiber Operator	Wärmeleistung in kW Thermal Output	maximaler thermischer Neutronenfluß max. Thermal Neutron Flux (n/cm²sek)	Kühlmittel Coolant
4. Gundremmingen b. Ulm/Donau	Siedewasser	Stromerzeugung	RWE, Essen (75%); Bayernwerk, München (25%)	801 000 (thermische Leistung 237 000 (elektr. Nettoleistung)		H_2O

Moderator Moderator	Kernbrennstoff Fuel	Herstellerfirma und deutsche Hauptkontraktfirma Designer and Principal German Contractor	Auftraggeber Ordered by	Finanzierung Financed by	Stand: Anfang 1964 Status: Early 1964
H_2O	angereich. Uran	International General Electric Operations SA (USA) mit AEG	RWE und Bayernwerk	RWE und Bayernwerk sowie Euratom (32 Mill. DM) ERP-Kredite u. Darlehen der Export-Import-Bank (USA); Gesamtkosten: etwa 350 Mill. DM	seit Ende 1962 im Bau

Tabelle nach Prof. Kliefoth (Schriftenreihe des Deutschen Atomforums)

XII TEILCHENBESCHLEUNIGER
ACCELERATORS

A) Einfachbeschleuniger

1. Kaskadenbeschleuniger (Cockroft-Walton)

Standort Location	Teilchenart Particle	MeV
U Marburg	e, p, d	2
U Frankfurt	p, d	1,5
MPI Chemie Mainz	p, d	1,2
U Mainz	d	1,5
U Göttingen	d	1
PTB Braunschweig	p, d	0,8
U Freiburg	p	0,6
TH Aachen	p, d	0,5/0,2
U Bonn	d	0,3
U Tübingen	d	0,2

2. Bandgeneratoren (Van de Graaff) – Lieferfirma: HVEC

Standort Location	Energie MeV Energy MeV	Teilchen-art Particle	μA	Magnete	Strahlrohre bzw. Experimentierpl.	in Betrieb
U Kiel	0,4	pos.	150	—	1	1962
U Gießen	0,4	pos.	150	—	1	1962
TH Hannover	0,4	pos.	150	—	1	1961
HMI Berlin	0,4	pos.	150	—	1	1963
RBW Marburg	0,4	pos.	150	—	1	1962
TH Darmstadt	0,4	pos.	150	—	1	1964
PTB Berlin	0,4	pos.	150	—	1	1963
		neg.	100			
TH München (Eig.)	2,0	pos.	0,2	1×90°	1	1962
U Erlangen (Eig.)	1,0	pos.	10	—	1	1958
DKI Darmstadt	1,3	neg.	250	—	1	1961
U Gießen	1,3	pos.	150	1×25°	3	1961
BfL Karlsruhe	1,3	pos.	150	—	1	1959
		neg.	250			
U Kiel	1,3	pos.	150	1×25°	3	1965
TH München	1,3	pos.	150	1×90°	2	1964
		neg.	250			
HMI Berlin	1,5	neg.	1 700	—	3	1962
GfK Karlsruhe	2,0	pos.	150	1×25°	1	1962
		neg.	250			
U Tübingen	2,0	pos.	150	1×25°	3	1964
U Frankfurt	2,0	pos.	150	1×25°	5	1964
BASF	2,0	neg.	250	—	1	1958
Farbenfabriken Bayer AG	2,0	neg.	250	—	1	1962
U Bonn	3,0	neg.	1 000	—	1	1957
	Injektor f. Synchrotron					
U Hamburg	3,0	pos.	750	1×25°	3	1959
	10 Nanosekundenpuls					
KFA Jülich	3,0	pos.	750	—	1	1961
(TH Aachen)		neg.	1 000			
MPI f. Kohleforschung	3,0	neg.	1 000	—	1	1963

Standort Location	Energie MeV Energy MeV	Teilchenart Particle	μA	Magnete	Stahlrohre bzw. Experimentierpl.	in Betrieb
Mülheim	Hochstrompulsung Pulsamplitude: 1,0 Amp. Pulslängen: 0,5; 1,5 und $4{,}0 \times 10^{-6}$ sec.					
GfK Karlsruhe	3,0 1 Nanosekundenpuls	pos.	750	1×25° 1×90° (Mobley)	3	1964
Siemens-Schuckertwerke Erlangen	3,0	pos. neg.	750 1 000	—	1	1963
Euratom C.C.R. Transuran-Institut Karlsruhe	3,0	neg.	1 000	—	1	1964
Leybold-Hochvakuum-Anlagen GmbH Köln-Bayenthal	3,0	neg.	1 000	—	1	1962
TH Stuttgart	4,0 Typ noch unbest.	pos. neg.	ca. 1 000	0—90° 1×90°	5	1966
U Freiburg	5,5	pos.	70	1×90° 1×45° 1×25°	10	1958
U Frankfurt	5,5	pos.	70	1×90° 1×25°	4	1961
HMI Berlin	5,5 1 Nanosekundenpuls	pos	70	1×90° 1×90° (Mobley) 1×45°	8	1965
MPI f. Kernphysik Heidelberg	12 Tandem	pos.	2	1×90° 1×45°	8	1961
U Erlangen	12 Tandem	pos.	2	2×90° (davon einer drehbar)	4	1964
U Köln	15 Tandem	pos.	15	1×90° 1×45°	8	1966
MPI f. Kernphysik Heidelberg	20 Tandem	pos.	25	1×90° 1×45°	8	1966

3. Scheibengeneratoren (Felici)

Standort Location	Energie MeV Energy MeV	Teilchenart Particle	µA	Lieferfirma
U Köln	0,6	pos.	1000	SAMES
U Hamburg	0,6	pos.	500	SAMES

B) Mehrfachbeschleuniger

1. Linearbeschleuniger

Standort Location	Teilchenart Particle	Energie MeV Energy	Lieferfirma Manufacturer	in Betrieb Completion Date
MPI Chemie Mainz U Mainz	e	285	CSF	1964
TH Darmstadt	e	60	Varian	1961
U Gießen	e	60	CSF	1966
Bundesanstalt f. Lebensmittelfrischhaltung, Karlsruhe	e	25	Varian	1965
U Bonn	e	20	Varian	1965
Rheinstahl AG, Heinrichshütte Hattingen	e	12	HVEC	1963

2. Cyclotrone

Standort Location	Polschuhdurchmesser Diameter m	Teilchenart Particle	Energie MeV Energy	Strahlstrom innen Beam Current internal µA	Strahlstrom außen Beam Current extracted µA	Lieferfirma Manufacturer	in Betrieb Completion Date
KFA Jülich	3,20	d/α	90/180	50	5	AEG	1968
GfK TH Karlsruhe	2,25	d/α	55/110	> 100	> 10	AEG	1963
U Hamburg	1,40	p	2–30	> 100	25	Philips	1968
		d	3–15				
		α	6–30				
MPI Heidelberg	1.01	d/α (He^3, He^4)	12/24	400	20	Eig.	1944

3. Mikrotrone

Standort Location	Polschuh-durchmesser m Diameter	Teilchen-art Particle	Energie MeV Energy
U Mainz	0,50	e	10
PTB Braunschweig	0,50	e	5

4. Synchrocyclotrone

Standort Location	Polschuh-durchmesser m Diameter	Teilchen-art Particle	Energie MeV Energy	Strahlstrom μA Beam Current	Hersteller Manufacturer	in Betrieb Completion Date
U Göttingen	1,80	d/α	28/56	25	Philips	1962
U Bonn	1,90	d/α	35/70	5	Eig.	1959

5. Elektronen-Synchrotrone

Standort Location	Bahn-durchmesser m Diameter	Teilchen-art Particle	Energie MeV Energy	Strahlstrom Beam Current μA	e/sec.	Hersteller Manufacturer	in Betrieb Completion Date
DESY Hamburg	101	e	6000	1	$5 \cdot 10^{12}$		1964
U Bonn	6	e	500	0,1	$5 \cdot 10^{11}$	Eig.	1959
U Bonn	22	e	2300	0,3	$2 \cdot 10^{12}$	Eig.	1968

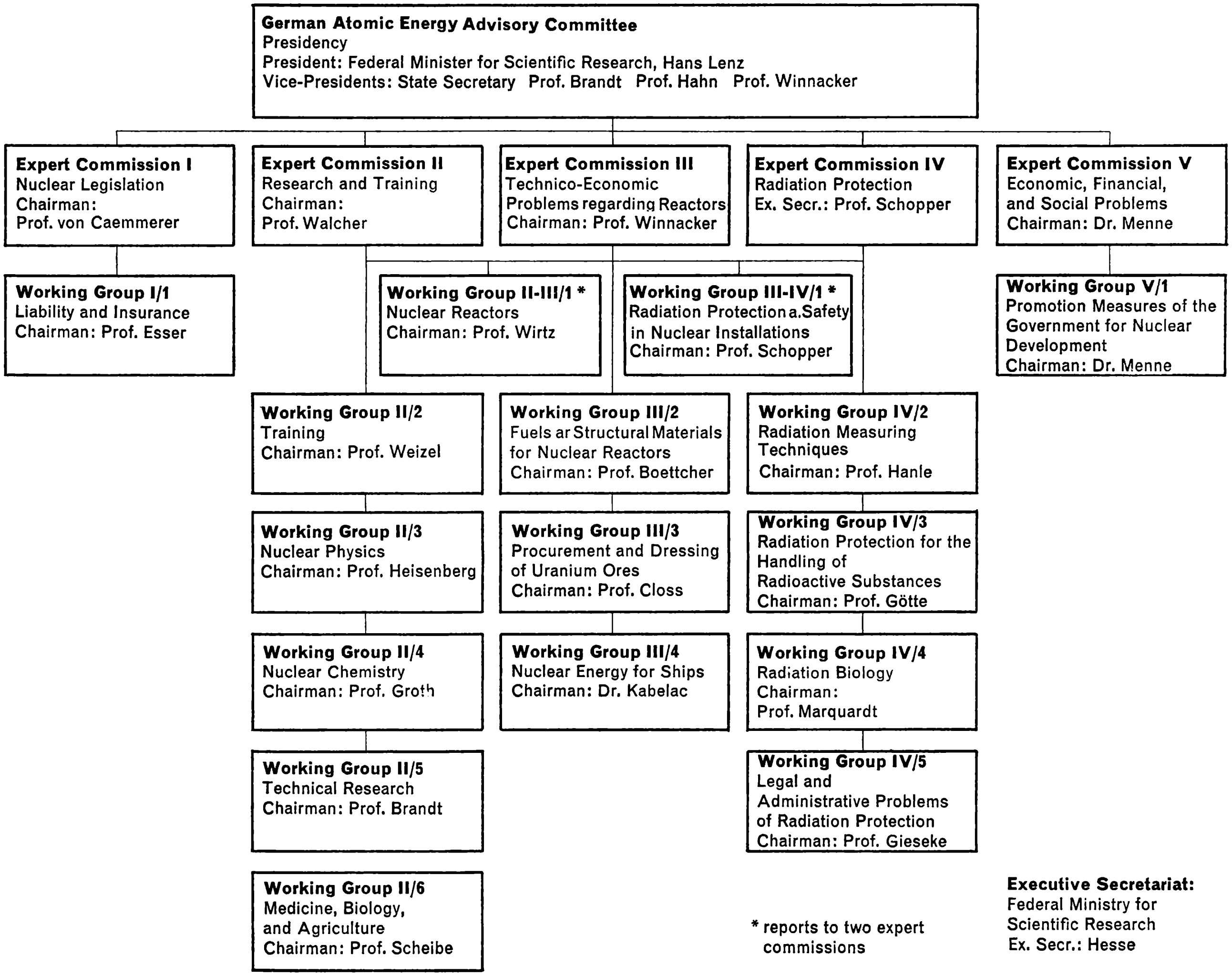
6. Betatrone

Standort Location	Bahnradius m	Teilchenart Particle	MeV
Siemens-Reiniger Werke Erlangen	0,21	e	35
MPI Biophysik Frankfurt	0,21	e	35
U Heidelberg	0,19	e	35
U Würzburg	0,20	e	35
TH Karlsruhe	0,24	e	31

U = Universität
TH = Technische Hochschule
DKI = Deutsches Kunststoffinstitut
BfL = Bundesforschungsanstalt für Lebensmittelfrischhaltung
Eig. = Eigenbau/Institute Design
PTB = Physikalisch-Technische Bundesanstalt

XIII ORGANIZATION OF THE ATOMIC ENERGY ADVISORY COMMITTEE

(DEUTSCHE ATOMKOMMISSION)



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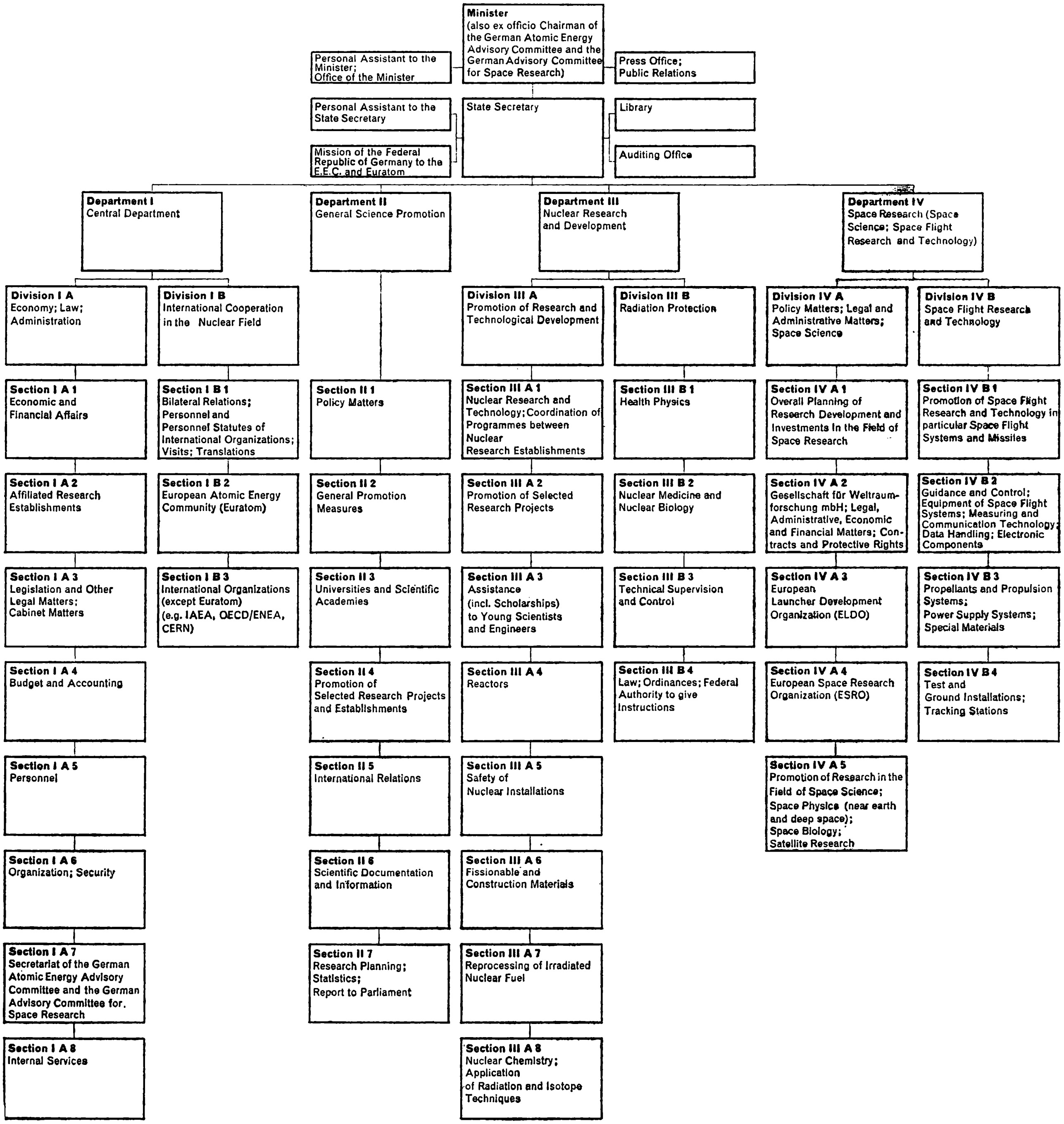
XIV ORGANIZATION CHART OF THE FEDERAL MINISTRY FOR SCIENTIFIC RESEARCH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Press Office; Public Relations
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Personal Assistant to the State Secretary
Mission of the Federal Republic of Germany to the E.E.C. and Euratom
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Type: 9/12 und 8/10 pt. Brete Grotesk
Graphic design by Rolf Lederbogen
Printed by Druckerei Schwann, Düsseldorf